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Edited by LEWIS STEPHEN PILCHER, M.D., LL.D., of New York
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Recorder of the American Surgical Association

SEMICENTENNIAL OF THE AMERICAN SURGICAL ASSOCIATION, 1879-1930
(CONTINUED)

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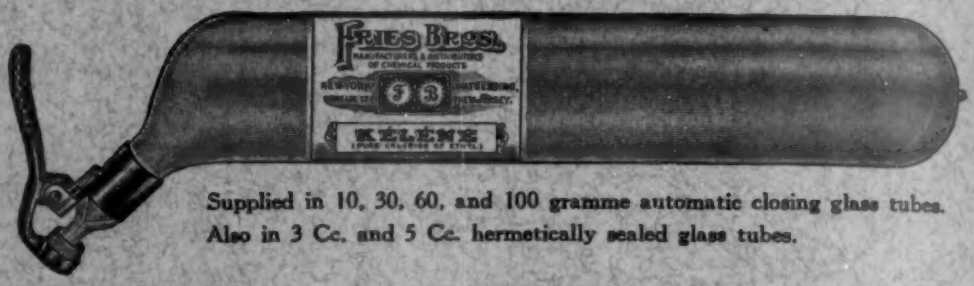

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ANNALS *of* SURGERY

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TRANSACTIONS AMERICAN SURGICAL ASSOCIATION

MEETING HELD MAY 15, 16 AND 17, 1930; *Continued.*

OBSERVATIONS ON POST-OPERATIVE PULMONARY ATELECTASIS

CONSIDERATION OF SOME FACTORS IN ITS ETIOLOGY, PREVENTION AND TREATMENT

BY HAROLD BRUNN, M.D., AND SELLING BRILL, M.D.

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DEPARTMENT OF SURGERY—DIVISION OF THORACIC SURGERY, UNIVERSITY OF CALIFORNIA MEDICAL SCHOOL*

OUR interest in the subject of atelectasis has extended over a considerable number of years. In May, 1928, in a discussion at the American Society of Thoracic Surgery, one of us[17] spoke of the use of CO_2 inhalations at frequent intervals for three or four days following operations. This procedure had been carried on more or less intermittently during the previous year with apparently good results. For some time there has been much discussion and experimental work on the mechanism, etiology, prophylaxis and treatment of post-operative pulmonary atelectasis. In the Clinic on Thoracic Surgery at the University of California Medical School, during the past year, a group has attempted to make careful observations on every patient operated upon. We have carried out these observations in considerable detail and we feel that these findings are worthy of tabulation.

The procedure consisted in the administration of CO_2 inhalations after every operation to produce hyperventilation, whether ether, gas, spinal or local anæsthesia was used. The CO_2 inhalations and changes in posture were repeated three or four times a day thereafter for the purpose of deciding whether or not such a procedure would diminish the incidence of lung complications. On all of these patients careful physical examinations were made of the chest and, so far as was possible, röntgenograms were taken before operation, and many times thereafter, with the first sign of symptoms referable to the chest. When lung complications supervened, CO_2 inhalations and postural changes, depending upon the location of the trouble, were carried out every two or three hours day and night. Certain adjuncts were at times applied, such as steam inhalations, potassium iodide medication, *etc.* Bronchoscopy was carried out in a certain number of patients where it seemed advisable. These observations and results were tabulated. Certain underlying factors were inquired into as closely as possible by laboratory methods. These are still being carried on and have not neared completion.

Composite Röntgen-ray Series. The first essential, obviously, is to know the condition of which we speak. We believe with Churchill[22] and others

* J. J. and Nettie Mack Foundation.

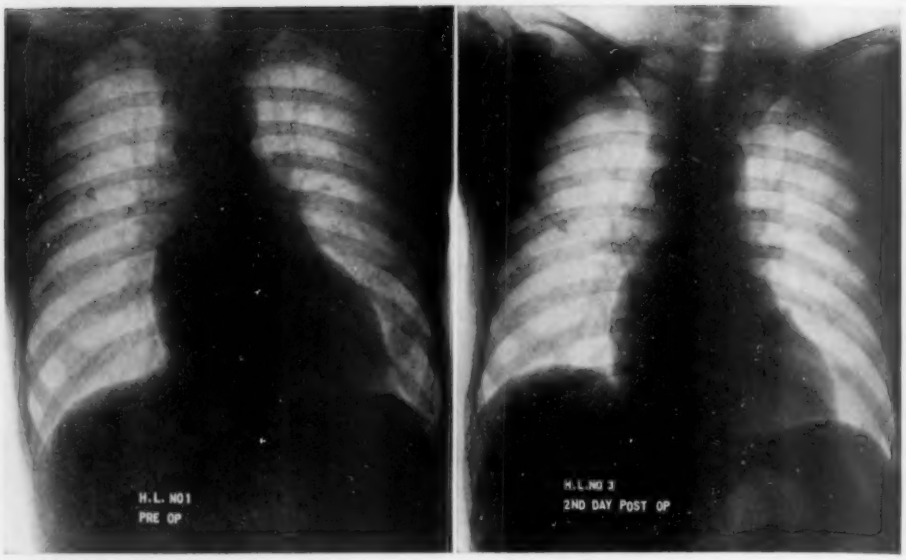

FIG. 1A FIG. 1B

FIG. 1.—Films of H. L., showing a minor degree of atelectasis. Note the increased height of the diaphragm and cardiac displacement in the post-operative film (No. 3), in comparison to the pre-operative film (No. 1). The lung fields are clear.

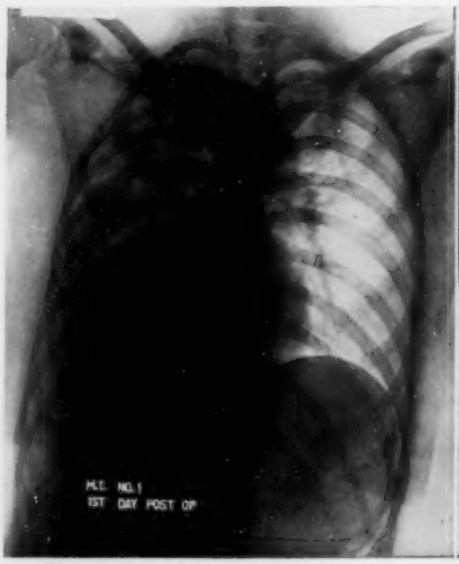

FIG. 2.—Massive atelectasis of the right lung. Film taken twenty-four hours post-operatively following D. & C. and uterine suspension. Gas-ether anæsthesia. Mucus + +. With CO_2 inhalations and postural drainage, chest cleared in two weeks.

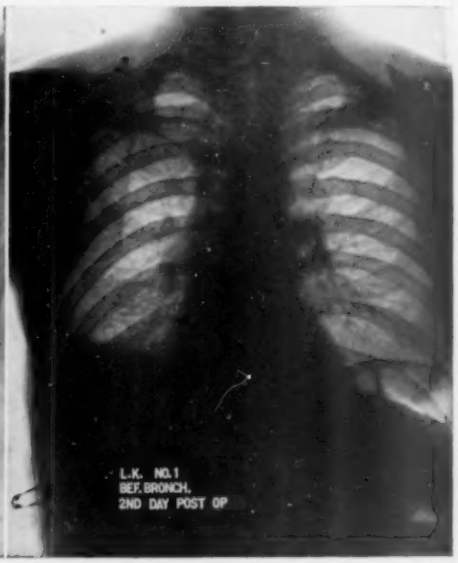

FIG. 3.—Atelectasis of the lateral part of right lower lobe; before bronchoscopy.

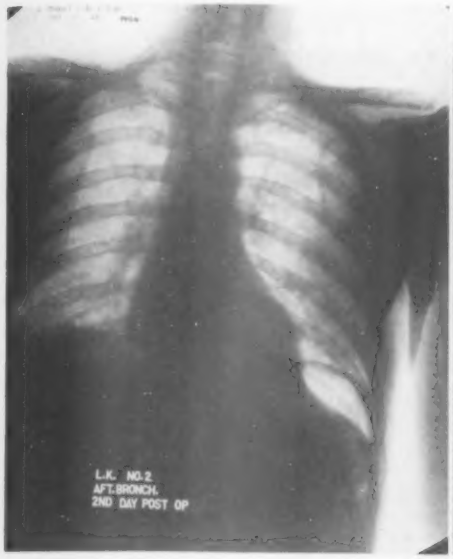

FIG. 4.—Same patient as Fig. 3 shortly following bronchoscopy and removal of plugs from lateral minor bronchi on right. Note clearing of shadow in the right lower lobe.

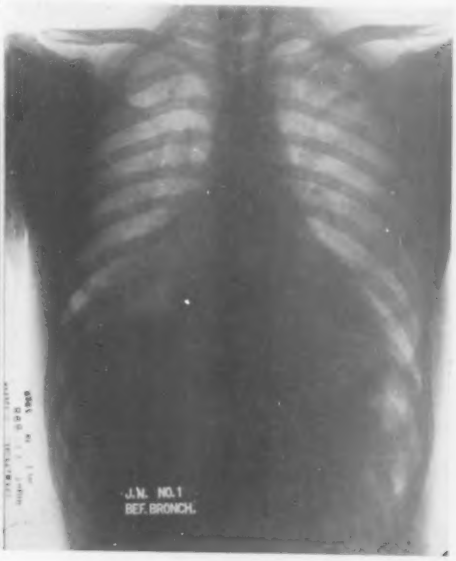

FIG. 5.—Example of atelectasis of the vertebral portion of the right lower lobe; before bronchoscopy.

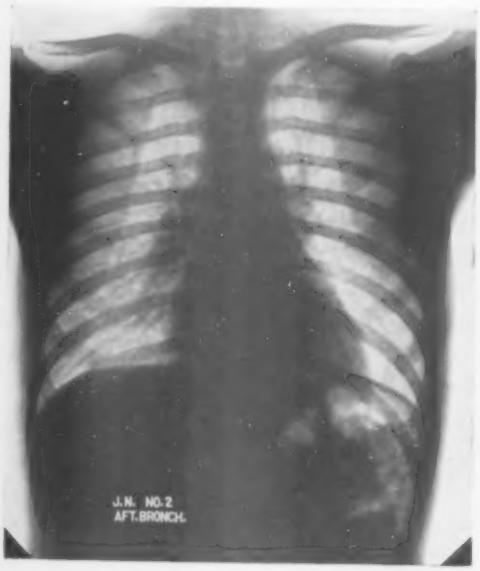

FIG. 6.—Same patient as Fig. 5 shortly following bronchoscopy and removal of plugs from posterior and vertebral minor bronchi on right. Note clearing of the vertebral portion of the right lower lobe.

FIG. 7.—Diagrammatic representation of the bronchoscopic findings of Figs. 3–4 and Figs. 5-6. In the centre, the right primary bronchus is depicted bifurcating into the middle and lower lobe bronchi. The location of the atelectatic portion of the lung of L. K. (Fig. 3) is shown on the right with the plugging of a lateral minor bronchus. On the left, the lesion of J. N. (Fig. 5) is shown with the plugging of the posterior and vertebral minor bronchi.

that massive collapse and various other types of atelectases are different stages of the same disease. It is well known that it occurs not infrequently in other conditions. We may have any stage of patchy, lobular, partial or complete atelectasis of part of a lobe, a whole lobe, a whole lung or both lungs. The symptoms and physical findings have been so well and completely covered in previous reports by practically all writers on this subject that there is no need of discussing them further. One must keep in mind that the symptomatology is not necessarily correlated with the extent of involved lung. The chief characteristic of the physical findings is their variability, so that two people examining the same patient within an hour may obtain entirely different findings. The Röntgen-ray is the most helpful adjunct we have in diagnosis and it would seem worth while to present films depicting different stages and types of atelectasis.

The smallest degree of atelectasis to take place post-operatively, as shown by the Röntgen-ray, has been clearly brought out by Muller, Overholt and Pendergrass,[58] and is what they term "pulmonary hypoventilation." Although they state that this condition should be regarded as normal, it might well be considered as a minor degree of atelectasis. They found it to occur "normally" only in upper abdominal operations. However, a similar appearance can be shown by Röntgen-ray following some lower abdominal operations and hernioplasties. Fig. 1 (H. L.) is an example of this very early change following a hernioplasty under gas and oxygen anæsthesia. He had no treatment and Röntgen-ray was essentially normal within four days. At the other extreme, there may be a complete collapse of the whole lung as is shown in Fig. 2 (M. T.). Between these two degrees of atelectasis there may be any extent of lung involvement. Fig. 3 (L. K.) demonstrates a collapse of the lateral part of the lower lobe of the right lung. The proof of this is shown in Fig. 4, the same patient after bronchoscopy and the removal of two small plugs from lateral minor bronchi. Similarly, the vertebral portion of the lower lobe alone may be involved as shown in Fig. 5 (J. N.). Fig. 6 (J. N.) is following the removal of small plugs by bronchoscopy from the posterior and vertebral minor bronchi of the right lung. Fig. 7 is a diagrammatic representation of the bronchoscopic findings in the previous two patients. A complete collapse of the lower lobe may occur, which is entirely opaque to the Röntgen-ray, as is shown in Fig. 8 (P. M.). Fig. 9 (B. V.) again shows a complete collapse of the lung, in this instance on the left side. The patchy, or bronchopneumonic type, is well illustrated in Fig. 10 (F. G.), or what might be called a pneumonic type, is seen in the Röntgen-ray in Fig. 11 (E. M.).

The cardinal signs of collapse, röntgenologically, are elevation of the diaphragm on the involved side, heart, mediastinum and trachea displaced to the affected side, contraction of the ribs on that side, and lung shadow. From the preceding plates, all of which are from proven cases of atelectasis, it can be seen that it is not necessary to have all of these on the film. One or the other of these findings may predominate. We have found the most constant sign to be the elevation of the diaphragm on the affected side. The

type of chest, that is, the mobility and flexibility of the thoracic cage and mediastinum and the location of the lesion, plays a most important part in determining the amount of change shown in the film. Usually, it is massive collapse only that gives all the cardinal signs in the Röntgen-ray plate.

The diagnosis of a pneumonic or a bronchopneumonic process on the Röntgen-ray film of any immediate post-operative chest complication should be looked at askance at the present stage of our knowledge. It is much more likely to be an atelectatic process. One of the films shown above (Fig. 5) was diagnosed pneumonia by five capable röntgenologists in San Francisco. Not until the plate following bronchoscopy (Fig. 6), was shown to them, would they admit that the process was atelectatic. The Röntgen-ray appearance in Fig. 11 could well have been diagnosed as a lobar pneumonia.

Recently Coryllos has doubted the independent identity of post-operative pneumonia. He[25] believes that atelectasis, post-operative pneumonitis, lobar pneumonia (whether lobular, lobar or massive) are produced by the same mechanism. He gives extensive clinical, pathologic and experimental data to support his theory. He thinks that they are all due to "a factor of great importance—*bronchial obstruction*. Any interference with the free drainage of the bronchial tree will cause lesions the nature, extent, importance and evolution of which will depend upon the degree and duration of the obstruction and nature and virulence of the microbes present."

Seventy-five to eighty years ago Gairdner[33, 34, 35] argued long and valiantly in an attempt to prove that atelectasis was an entirely different condition than pneumonia. We have not the wealth of evidence to offer that either Gairdner or Coryllos present but, from careful clinical and bronchoscopic observations, we believe that although the majority of post-operative complications are atelectatic, there are some that are of a different nature. An example of this type of complication is illustrated by the following case.

H. B., female, aged seventeen, was operated upon for acute appendicitis under nitrous oxide and ether anæsthesia. Her pre-operative plate (Fig. 12, No. 1) was entirely negative. Thirty-six hours after operation she developed high fever, elevated pulse rate, and respiratory rate of 40. Her clinical chart is shown (Fig. 13). She had little cough and no sputum. Röntgen-ray examination at this time was still negative (Fig. 14, No. 2). Forty-eight hours after operation the chest film showed a shadow immediately about the left hilus (Fig. 15, No. 3). As is shown in her succeeding chest films (Figs. 16 and 17, Nos. 4 and 5), the process was interpreted as a central pneumonia of the lobar type which gradually cleared (Fig. 18, No. 6). At no time was there any evidence by physical signs or Röntgen-ray that this was other than a pneumonic process. This patient had no sputum and, therefore, no culture could be obtained. Bronchoscopy was not performed since there was no indication that it would be of any aid in treatment. The clinical chart was different from the type of chart shown by the post-operative atelectatic patient.

ETIOLOGY

The most fascinating part of this problem is its etiology, which has been heatedly discussed for over a hundred years. Interestingly, this condition was first described in children dying shortly after birth by various German writers, beginning with Schenk,[74] in 1811. They, however, did not

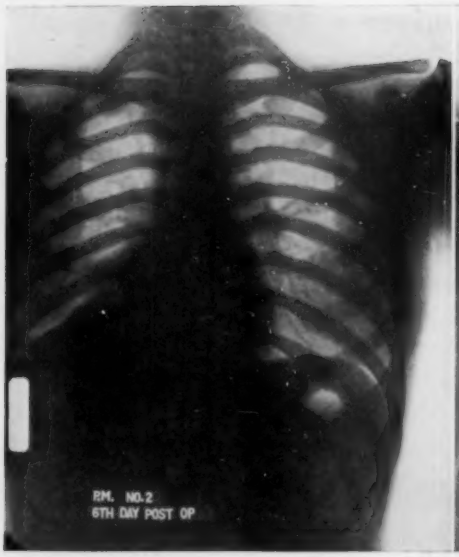

FIG. 8.—Film showing complete atelectasis of the right lower lobe. Diaphragm cannot be seen. Note the heart displacement and dense shadow representing collapsed right lower lobe.

FIG. 9.—Film showing complete collapse of left lung. Note the cardiac shadow entirely hidden in left chest.

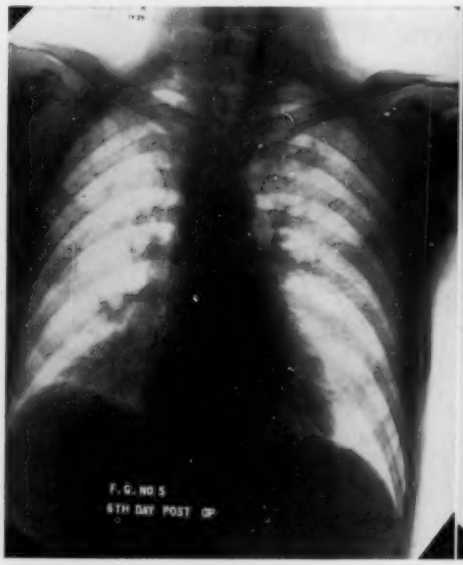

FIG. 10.—Film showing bronchopneumonic type of atelectasis. This film was diagnosed pneumonia before bronchoscopy was performed.

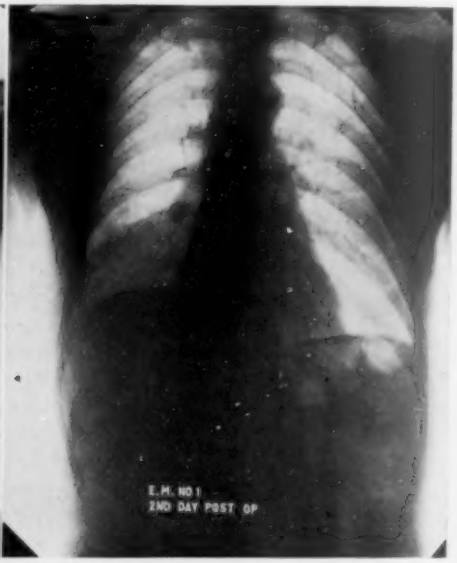

FIG. 11.—Film showing lobar-pneumonic type of atelectasis. Note the height of the diaphragm and cardiac displacement. With vigorous treatment by CO_2 inhalations and postural changes physical signs practically cleared in two hours. The shadow in the right lower chest had disappeared in the film of the following day.

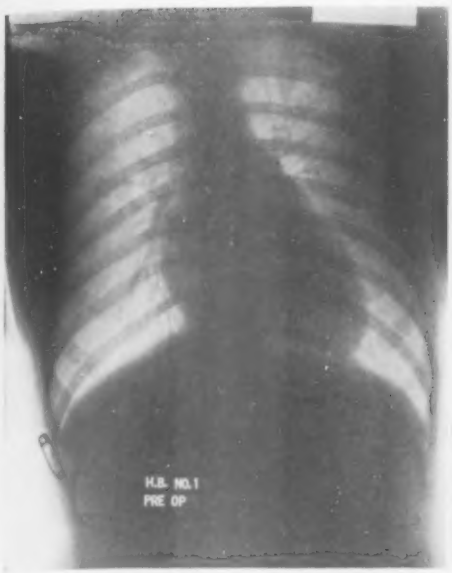

FIG. 12.—Pre-operative film of H. B. Chest negative.

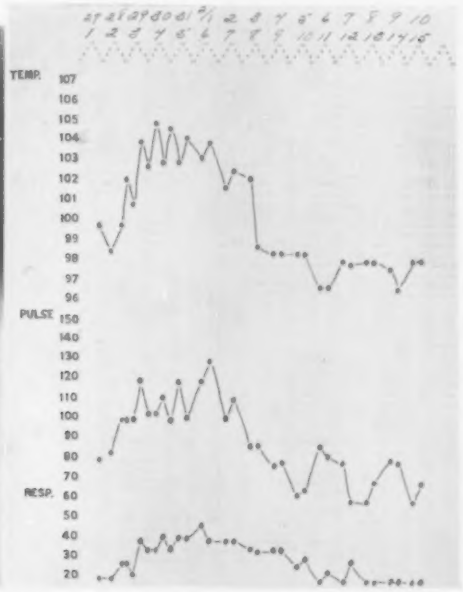

FIG. 13.—Clinical chart of H. B. Note the abrupt rise in temperature and return to normal by crisis; also, the rapid respiratory rate which was sustained thoughout her illness. We did not find this typical in our atelectatic cases.

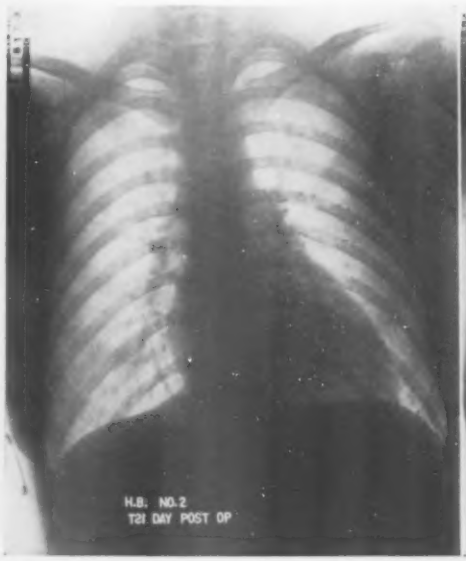

FIG. 14.—Chest still negative. Note that there is not any displacement of the cardiac shadow. The diaphragm is not elevated and ribs are not contracted.

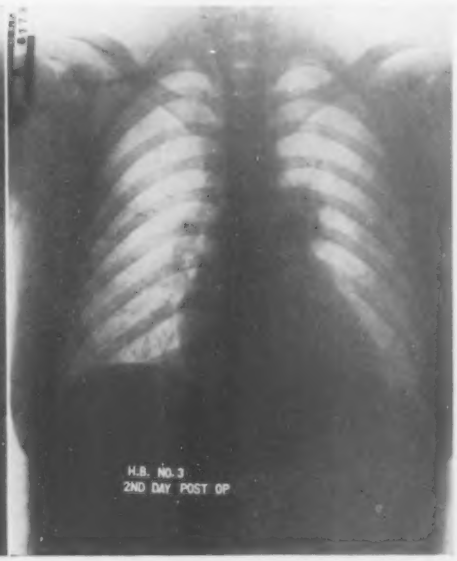

FIG. 15.—Note the shadow about the left hilus, apparently a beginning central pneumonia. There is still no displacement of the cardiac shadow or diaphragm.

understand it. Louis,[54] in 1829, was the first to describe this lesion in adults and the name atelectasis was given to it by Jörg,[45] in 1835. This author had previously described it in children in 1832. He coined the word *atelectasis* from two Greek words, ατελής, meaning imperfect, and ἔκταβις, meaning expansion. For a complete historical survey of the subject, the report of Bowen[8] should be consulted. Clinically, the medical aspects of this condition were most carefully studied and described by W. T. Gairdner[33, 34, 35] in a series of papers beginning in 1850. Gairdner firmly believed the chief factor in the production of this condition was bronchial obstruction. So bronchial obstruction was the earliest and, as we shall see, is also the most recent of the causes given for the production of atelectasis.

Evidence favoring bronchial obstruction.—There is an overwhelming array of evidence, both experimental and clinical, favoring the theory of bronchial obstruction as a prime factor in the production of pulmonary atelectasis, whether it be post-operative or not.

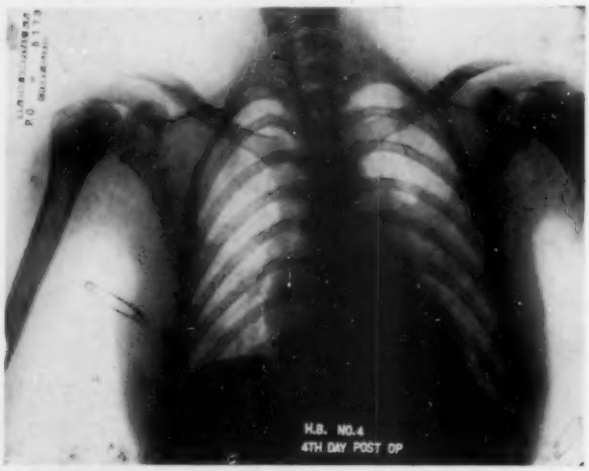

FIG. 16.—Film showing diffuse density of left lower chest with no displacement of heart or diaphragm. Ribs are not contracted.

Mendelssohn,[57] in 1845, showed experimentally that the introduction of foreign bodies—shot, paper ball, thick watery solution of gum arabic—into the air passages, narrowing of the trachea by means of a ligature, opening the pleural cavity or section of both recurrent laryngeal or both vagus nerves, was followed by atelectasis. Traube,[83] in 1846, showed that the atelectasis following section of the vagus or recurrent laryngeal nerves was due to the entrance of buccal secretion into the air passages. In 1878–1879, a very illuminating series of experiments were published by Lichtheim,[51] who obstructed the bronchus in rabbits by the introduction of a laminaria plug without opening the thorax. As the plug swelled, the lung beyond collapsed. Collapse did not occur when the blood-vessels to the lung were tied. He also sectioned the phrenic nerve and the spinal cord at the second and third cervical segments. No collapse occurred. He went further and established the speed of absorption of the different gases. Thus, operating on rabbits, he found that after obstruction of the bronchus, pure oxygen is completely absorbed in forty-five minutes and carbon dioxide in from ten to thirty minutes, whereas the nitrogen is absorbed only after twenty-four hours.

During the next fifty years there was little experimental work on this subject. MacCallum,[55] in 1908, had one of his students introduce a pea into the bronchus of a lobe of the lung in dogs. This pea was impacted there in such a manner as to completely obstruct the flow of air to that lobe. At autopsy this lobe was found to be atelectatic and, it is interesting to note, the bronchus behind the obstruction was found to be filled with thick mucus.

Andrus[1] produced a collapse of the left lung in dogs by ligating the left primary bronchus. The lung became completely atelectatic under these condi-

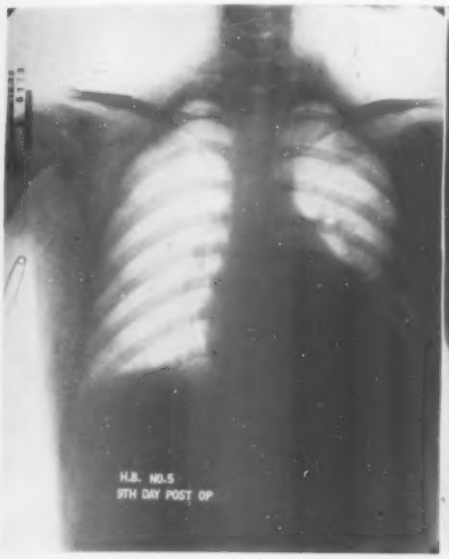

FIG. 17.—Similar appearance to Fig 16. There is some apparent displacement of the cardiac shadow, but at this time the patient was practically well, as shown by the chart, Fig. 13.

FIG. 18.—Film showing chest returned to normal.

tions within three days after operation. After four months he found a definite and marked fibrosis of the collapsed lung. In the discussion of this report. Archibald states that Scrimger had performed similar experiments with like results.

In 1928, Coryllos and Birnbaum[24] reported the production of atelectasis in the dog by plugging the bronchus with a rubber balloon. By placing the animal in a specially constructed negative pressure box with the chest opened, they were able to watch the development of the atelectasis in the involved lung or lobe. They found that the time necessary for the establishment of atelectasis when the lung was filled with oxygen was about one-half hour, but, when the lung was filled with air, it took about twelve and one-half hours to cause a complete atelectasis, although the process was marked at the end of six hours. Almost simultaneously Lee, Ravdin, Tucker and Pendergrass[48, 49] produced massive atelectasis in the dog by obstructing the bronchus with the tenacious bronchial secretion removed from the bronchial tree of a patient with

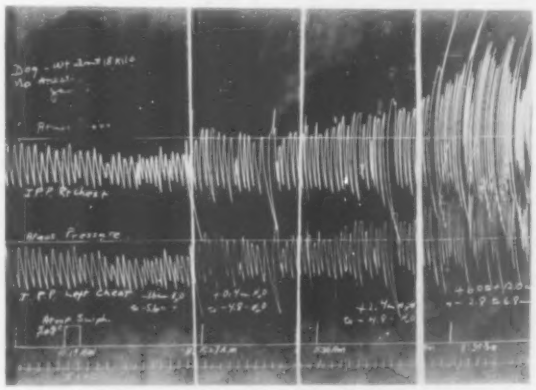

FIG. 19.—Kymographic record of intra-pleural pressures of both chests of a dog following subcutaneous administration of six milligrams of atropin. Horizontal lines are the atmospheric pressures in each chest. Above the horizontal lines the pressures are greater than atmospheric and below are subatmospheric. The down swing of the curve is inspiration and the up swing is expiration. The figures on the graph indicate actual pressure measurements in centimetres of water.

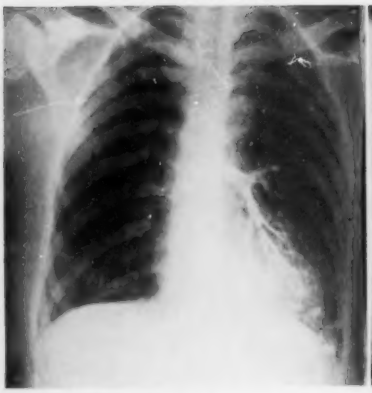

FIG. 20.—Introduction of lipiodol into primary bronchus of left lower lobe with the patient in the erect position.

FIG. 21.—Same patient as Fig. 20, turned on the right side, showing lipiodol draining into the right lung.

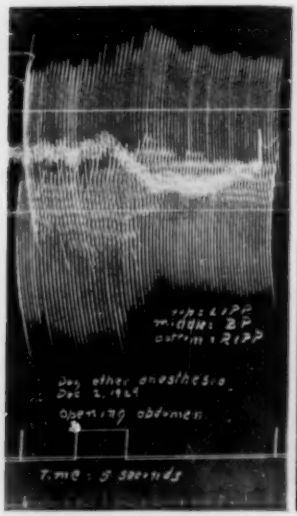

FIG. 22.

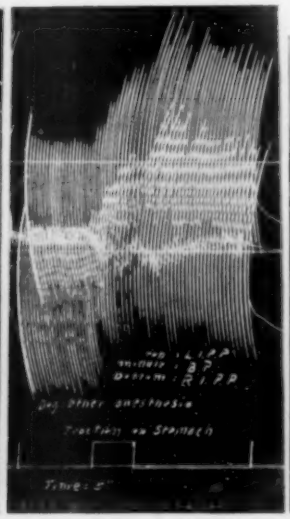

FIG. 23.

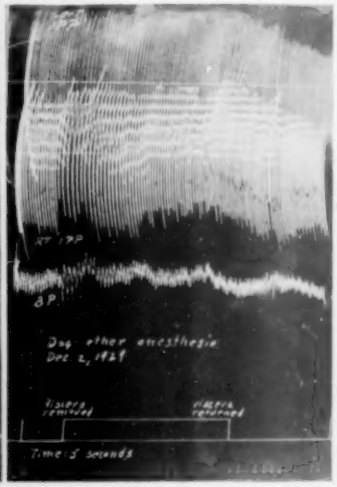

FIG. 24.

FIG. 22.—Kymographic tracing of intra-pleural pressures of both chests and blood-pressure of a dog under ether anæsthesia showing the effect of opening the abdomen. For explanation, see Fig. 19. Note blood pressure curve in centre, superimposed on intra-pleural pressure curves.

FIG. 23.—Kymographic tracing of intra-pleural pressures of both chests and blood-pressure of a dog under ether anæsthesia showing the effect of traction on the stomach. Blood-pressure tracing is superimposed on the intra-pleural pressure curves. For explanation see Fig. 19.

FIG. 24.—Kymographic tracing of intra-pleural pressures of both chests and blood-pressures of a dog under ether anæsthesia showing the effect of removing and replacing abdominal viscera. For explanation see Fig. 19.

massive atelectasis. They emphasized the importance of inhibiting the cough reflex in their animals by the use of sodium amytal.

There have been various explanations as to the fate of the pent-up air in the obstructed lung. The theory that the air of the obstructed lung was absorbed by the blood was first suggested by Fuchs,[32] in 1849, and again by Bartels,[6] in 1861. That this was possible was shown by Lichtheim as mentioned, and, more recently, by Van Allen and Adams.[84] Gairdner,[33] in 1850, suggested that the air was probably expelled by the plug in the bronchus acting the part of a ball valve, allowing the air to escape in expiration, but preventing the access of air in inspiration. Although Jackson[43] and others also believed this to be possible, the theory has been generally given up by most writers on this subject.

Clinical support of the bronchial obstruction hypothesis begins with Gairdner, who discussed in great detail the different types of various secretions that may be found in the bronchi and pointed out that such inspissated mucus could act, and does act, as an obstruction plug. He concludes in his report of 1850: "On reviewing the whole of the facts here presented to the reader, I think that the frequency of collapse of the pulmonary tissue, both in the adult and the child, must be considered as established, and its connection with bronchial obstruction rendered at least extremely probable."

The first to stress the importance of obstructing bronchial secretion in *post-operative atelectasis* were Elliott and Dingley,[29] who studied very carefully eleven cases of post-operative massive collapse. They noted that the viscid muco-purulent expectoration was uniform in all their cases and that this sputum was different in type from pneumonic sputum. More convincing evidence was given by the bronchoscopists[38, 44, 47] from Jackson's clinic who were able to cure clinically the atelectasis by removing the obstructing tenacious secretion, or plug, by the bronchoscope. Cases of recurrences, such as the patient reported by Hearn and Clerf,[38] who was drained seven times, add weight to this hypothesis. A very interesting case has been recently reported by Mathes and Holman[56] in which the patient was able to tell from his symptoms and by a peculiar whistling sound in his chest when the bronchial obstruction was dislodged and so could himself foretell the onset of reinflation of his atelectatic lung. The two cases whose films are shown above (Figs. 3, 4, 5 and 6) also offer rather convincing evidence that the removal of plugs from small minor bronchi almost immediately clears local atelectasis. It has been a common observation that the lung, distal to a bronchus obstructed by a foreign body or tumor, collapses. Reviewing all this evidence, it would seem almost impossible to deny that bronchial obstruction plays a most important rôle in the production of atelectasis. However, there is a surprisingly large amount of data against the bronchial obstruction theory.

Evidence against bronchial obstruction.—Wm. Pasteur,[63, 64, 65] who revived our interest in atelectasis and first emphasized the importance of post-operative atelectasis, never[67] has accepted the bronchial obstruction theory. In his letter[66] to "The Lancet," in 1914, in answer to Elliott and Dingley, he mentions the occurrence of a well-marked case of post-operative collapse without any cough or expectoration. He believed paralysis of the diaphragm and inability of the respiratory muscles to carry on their function properly to be a prime factor in the production of this complication. In this he was undoubtedly influenced by his early observations on atelectasis in post-diphtheritic paralysis.

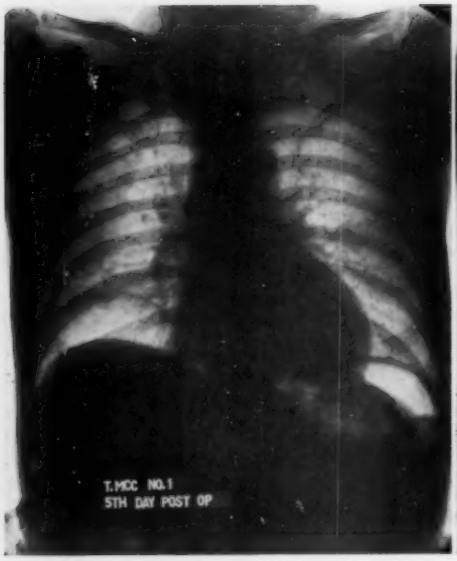

FIG. 25.—Chest film of patient following hernioplasty showing large collections of air under both diaphragms which gave signs in both bases.

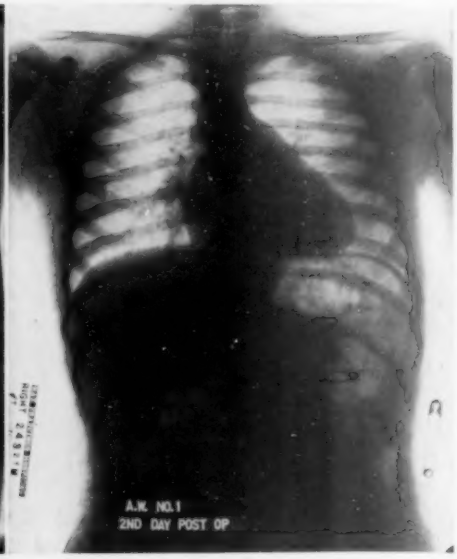

FIG. 26.—Film showing effect of abdominal distention on heart, diaphragm and lungs.

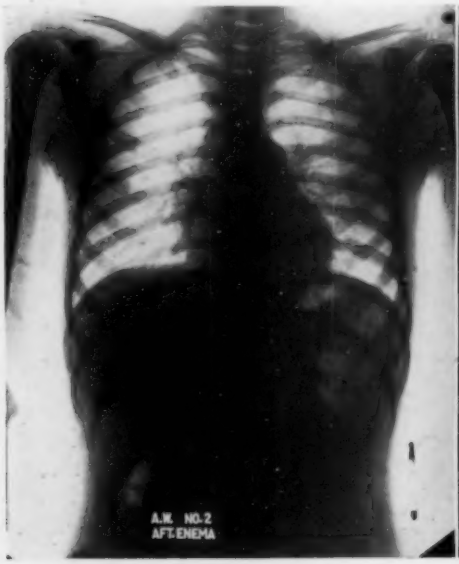

FIG. 27.—Same patient as Fig. 26 following soapsuds enema.

FIG. 28.—Chest film of adult showing effects of abdominal distention.

John Rose Bradford[9, 10] argues rather convincingly against bronchial obstruction as the etiological factor in the war-injury cases he observed. He claimed that there was no evidence of any gross obstruction in the larger bronchi. He stated further that there was definite post-mortem evidence that massive collapse might be present and yet no gross obstruction in the main bronchi found. He described one case of massive collapse of contralateral type, resulting from a non-penetrating wound of the chest wall, in which the soldier had walked four miles after being wounded. Such an instance is difficult to explain by the bronchial obstruction theory.

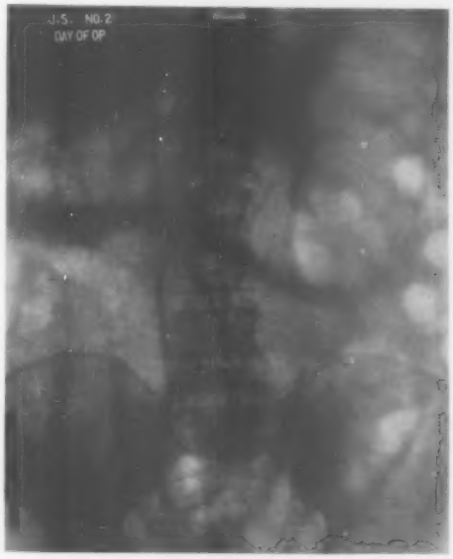

FIG. 29.—Abdominal film of patient shown in Fig. 28. Taken at the same time.

Briscoe's[14] experiments might be used as an argument that at least partial collapse in localized areas of the lung might take place as a result of injury to the innervation of the respiratory muscles, although his conclusion is that post-operative massive collapse may be produced by diaphragmatic pleurisy. Santee[72] reports two cases of bilateral massive collapse in which there was not any evidence of bronchial obstruction at autopsy. His first case died on the operating

FIG. 30.—This film shows an atelectasis on the right side with fairly marked elevation of the diaphragm and cardiac displacement.

FIG. 31.—Same patient as Fig. 30 following CO_2 inhalations and postural changes.

table. Bergamini and Shepard[7] also report two cases of sudden death during operation in which bilateral massive collapse was found at post-

mortem. They were unable to find even secretion in the bronchi. Such cases offer a powerful argument against the obstruction theory being the only etiological factor in the production of atelectasis and also makes us wonder how the gases in the lungs could have been removed so quickly by the blood-stream.* Experimentally, it has been shown that, following bronchial obstruction, it takes several hours at least for the contained air to be absorbed by the blood. Coryllos' observations have been mentioned. According to Archibald,[2] Scrimger found that after ligating a bronchus of a lobe to produce collapse, it took about twenty-four hours for the air to be absorbed.

Ball[5] reports four cases of pulmonary atelectasis following operation on the thyroid gland. In all of these the recurrent laryngeal nerve had been injured and tracheotomy had been performed. At necropsy obstructing material was carefully searched for, even in the smaller bronchioles, but none was found. The pulmonary vessels were carefully examined for emboli and none found. He believed that the injury to the laryngeal nerves was the important factor in the production of atelectasis in these cases. In another report,[4] he tells of another fatal case of bilateral lobar atelectasis associated with acute pancreatitis. Here, again, no obstruction was found in the bronchial tree. In this case he believed that fixation of the diaphragm was the chief factor.

Lilienthal,[52] while operating on a fibroma in the upper part of the thorax, observed the sudden collapse of the right upper pulmonary lobe. The operation was performed under intra-pharyngeal pressure. The patient died within forty-eight hours and at necropsy the lobe was still collapsed. Lilienthal states: "There was no possible reason to think that there was any obstruction in the bronchus of this patient and there certainly was none at the time of post-mortem section."

The cases reported by Sante[70, 71] may also be used as evidence against the bronchial obstruction hypothesis. However, he did have his patients cough, and plugs, or secretion, may have been dislodged in coughing, although Sante did not believe that this took place.

A most interesting case has been reported by Overholt, Pendergrass and Leopold.[59] This patient had no cough or sputum at any time or any evidence of increased bronchial secretion. Yet she developed a complete massive collapse and cleared with essentially no treatment.

Bradford[9] made an interesting observation that he did not note any case of collapse in head injuries or injuries of the upper extremities. There are practically no cases of atelectasis reported following cranial operations and the neuro-surgeon is not troubled with this complication.† Many of these brain cases are under ether and in one position for hours and, except for the fact that their respiratory muscles are usually unimpeded, these cases have all the factors favoring the production of mucous secretion and, therefore, atelectasis should occur.

Van Allen and Adams[84] reported a very interesting series of experiments. In one animal, kept under quiet respiration, they plugged a bronchus completely for forty-five days and found no atelectasis. They also produced bronchial obstruction with gum acacia, as reported by Lee and Ravdin, and in two dogs with quiet respirations atelectasis did not occur. They were able to produce atelectasis in the experimental animal only when they caused straining respirations.

*Since this paper was written, Coryllos adequately explains the absorption of the intra-pulmonary gases in these cases in Surg., Gynec., and Obst., vol. i, p. 801, 1930.

† Personal communication from Dr. Howard C. Naffziger.

In our laboratory, Brill and Brown[11] have produced mucous plugs in the bronchus of a dog by a method to be described later. When no other complicating factors were present, atelectasis was not produced.

From the above, it can be seen why there are proponents favoring etiological theories, other than bronchial obstruction, for the production of atelectasis. The mere fact that experimentally atelectasis has not been produced by any other method should not be used as too strong an argument against other theories.

Other theories.—There is very little in post-operative atelectasis, as we now know it, to support the theory of Pasteur that it is caused by paralysis of the diaphragm or chest musculature. Churchill[22] reports a case of a woman, aged fifty-two, who sustained a fracture of the cervical spine with almost complete transverse myelitis at the level of the fifth cervical segment. This lesion produced paralysis of all the respiratory muscles, except the diaphragm. She developed a partial collapse of the left lung. He states she was subject to repeated spells of dyspnœa and unproductive cough. This case may then partially support Pasteur's hypothesis. This theory now has practically no supporters, however, although Bradford[9] and Soltau[81] both believe that a reflex paralysis of the muscles of respiration might produce atelectasis.

Besides this reflex action there are two other reflexes which have to be seriously considered. Probably the most important is a reflex by way of the vagus which directly affects the lung and so may cause a collapse. Secondly, there may be a vasomotor reflex which could cause an increased outpouring of secretion in the bronchial tree or some other circulatory change which might conceivably produce atelectasis. Such a mechanism has been suggested by Gwyn[36] and Scott.[75, 77] A strong argument against the nervous origin of atelectasis is that the experimental worker has been unable to produce it by any nervous mechanism. Coryllos[25] points out that no one has given "an exact and precise description of the reflex involved or of the nature of the stimulus itself." However, we should not consider such negative arguments too strongly until it can be shown that another etiological factor, such as bronchial obstruction, can explain all types and cases of atelectasis.

It is well known that surprising phenomena occur as a result of reflex action. Carlson and Luckhardt,[20] working on turtles and frogs, have shown that reflex lung contractions can be induced from stimulation of the sensory nerves of the respiratory tract and mechanical stimulation of the larynx and the nares. They also found that mechanical and electrical stimulation of the alimentary tract, genito-urinary tract, gall-bladder, spleen, central ends of the visceral sympathetic nerves, cutaneous nerves, the cornea and the central end of the sciatic or brachial nerves induce reflex lung contractions which may be very marked. This work is quoted by many as a possibility that the vagus could easily be a path for reflexes causing atelectasis.

The work of Dixon and Brodie[26, 27] is also used in support of the vagal reflex theory. They conclude that the broncho-constrictor fibres run in the vagus only and the contraction of the bronchioles may lead to collapse or over-

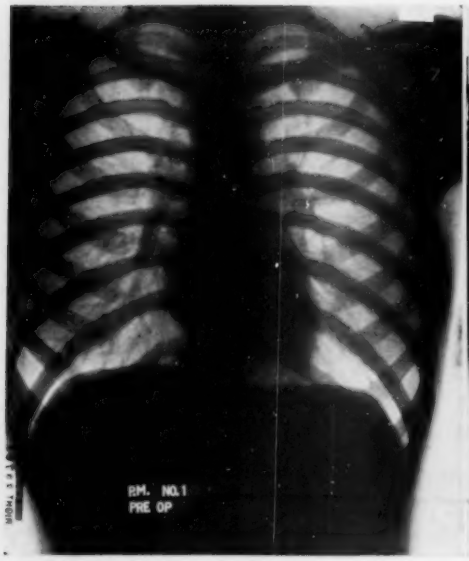

FIG. 32.—Pre-operative chest film showing normal chest.

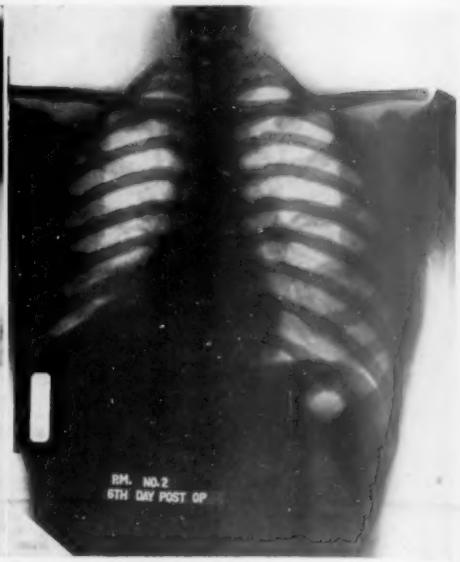

FIG. 33.—Film of same patient as Fig. 32, six days following hysterectomy and left oophorectomy. Spinal anæsthesia. Was very dyspnœic and uncomfortable. T. 103°, P. 114, R. 26. (Same as Fig. 8.)

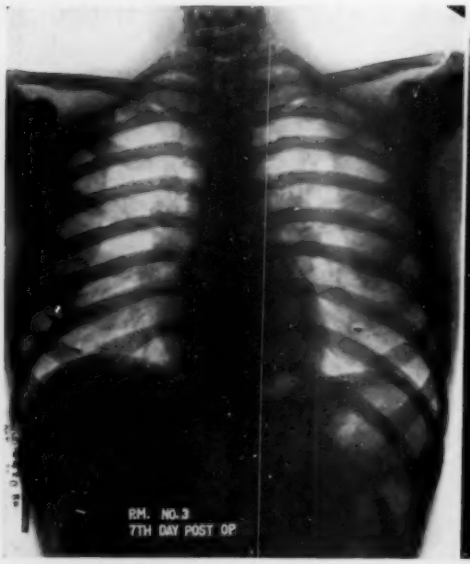

FIG. 34.—Same patient as Figs. 32 and 33 ten hours following bronchoscopy, which showed general tracheitis and bronchitis with much pus, especially in the right lower lobe bronchi. Pus aspirated.

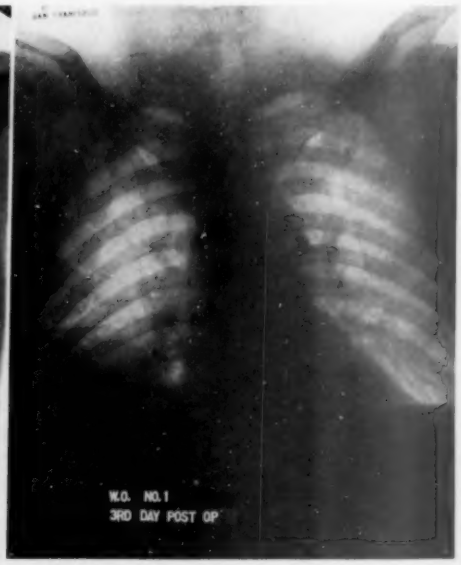

FIG. 35.—Chest film three days following appendectomy under spinal anæsthesia. Note shadow, lateral portion of right chest, and compare with Fig. 3 of L. K.

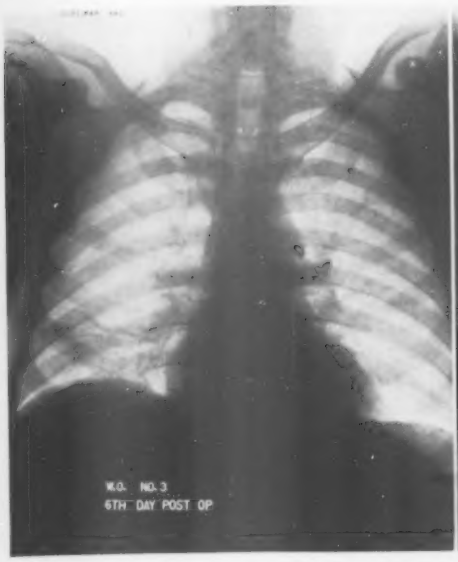

FIG. 36.—Same patient as Fig. 35 following removal of viscid sputum which was chiefly in the right lower lobe bronchi.

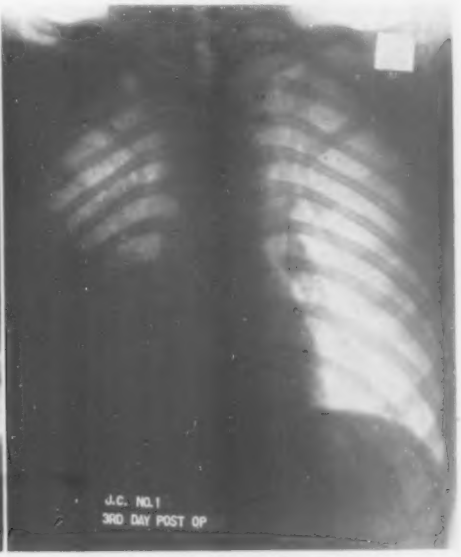

FIG. 37.—Film of patient following appendectomy under spinal anæsthesia showing practically a massive collapse of the right lung.

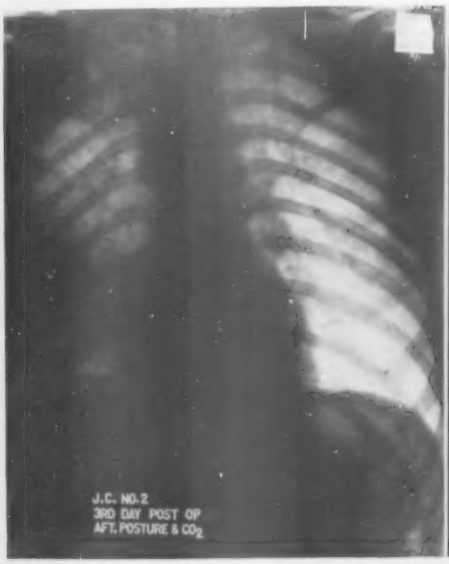

FIG. 38.—Same patient as Fig. 37 a few hours later after treatment with CO_2 inhalations and postural changes.

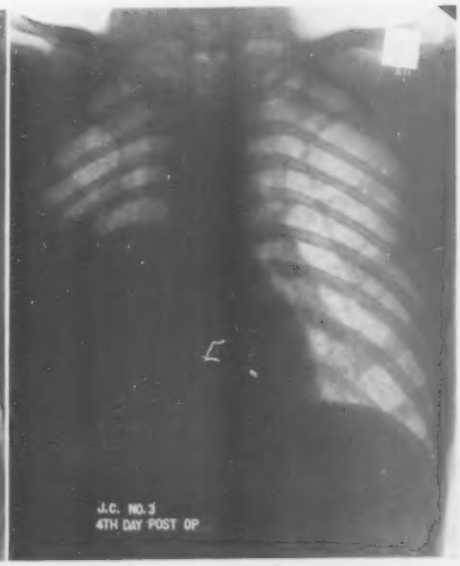

FIG. 39.—Same patient as Figs. 37 and 38 showing recurrence on the following day.

distention of the lung, depending upon the force of the inflation on the one hand, and the time allowed for deflation on the other. In the dog and rabbit, typical bronchiolar constriction immediately follows vagal stimulation.

Fontaine and Herrmann[31] sectioned the extrinsic nerves leading to the left lung in ten dogs. One of these animals suddenly expired on the third day, after having apparently recovered from the operation. At autopsy they found a typical massive atelectasis of the entire left lung and a partial atelectasis of the lower lobe of the right side. They found no obstruction and practically no secretion in any of the larger or minor bronchi. This experiment could be used to throw doubt on both the obstruction and reflex theories since the nerves leading to the left lung had been sectioned. Coryllos,[25] however, believes a pneumothorax occurred in this animal.

Scrimger[79] found that ligature of the small bronchial branches of the vagus with the lung expanded resulted after a delay of a few hours in local areas of collapse, roughly corresponding to the branches ligated. The collapse did not appear at once, and, in his opinion, was due to the absorption of the distal air.

The cases of contralateral collapse which occur shortly after a minor injury are perhaps most easily explained by some type of reflex. At any rate, the reflex theory cannot be entirely discarded at present. There is still a possibility of some type of local œdema, either angioneurotic or due to local irritation, causing an atelectasis of the lung distal to the lesion. That such a localized inflammatory œdema may take place and be the cause of atelectasis has been mentioned by Lord,[53] although he states that it is caused by proximity to an area of bronchopneumonia. One of our group[16] observed a localized area of œdema extending from just above the bifurcation of the trachea down into, and completely involving, the right primary bronchus, practically obliterating its lumen. After epinephrine application it opened up a bit and on the following day the bronchus was practically normal. Bergamini and Shepard thought that their cases were best explained by angioneurotic œdema. Reviewing all the evidence presented as to the etiology of post-operative atelectasis, we must say that at present bronchial obstruction is the most important single factor we know, but cannot say that it is the only factor, or the sole factor.

CONSIDERATION OF CERTAIN FACTORS

Pre-operative.—There are certain factors, pre-operative, operative and post-operative, which, either alone or in combination with bronchial obstruction, aid the production of atelectasis or play a part in initiating the process. Pre-operatively, we should consider first the length of time and the position in which the patient is kept in the hospital. Schaack[73] reports that a group of patients who were kept in the hospital two weeks or more had four times the incidence of post-operative pulmonary complications in comparison with a similar group who were in the hospital only two or three days. He stated further that the incidence of pulmonary complications in both groups was markedly decreased when pulmonary exercises were induced. It is well known that whenever any patient is kept quietly in bed for an extended

period of time, localized areas of atelectasis are very prone to occur. This is especially true in young children, in the aged and the debilitated.

The existence of previous pulmonary disease may play a part in any chest complication. There may be increased bronchial secretions in the bronchial tree favoring plugging. It is well known that in cases of bronchitis there is often a profuse outpouring of secretion during and immediately after the operative procedure. There is always a possibility in a case of bronchiectasis or lung abscess for the pus to cause an atelectasis, whether the patient is operated upon or not. An interesting case of lung abscess with atelectasis has been reported by Elwyn.[30] There is also the possibility of the pulmonary lesion acting as a focus from which organisms may invade a beginning atelectasis, making it more extensive and more serious.

We did not find that the time of year played much part in the incidence of pulmonary complications in our series. Ravdin and Kern,[46] however, found that there was a definite increase in pulmonary complications in the winter and spring which followed the increased incidence of pneumonia on the medical side.

It is well known that lung lesions, cardiovascular disease and acute abdominal lesions—upper abdominal, in particular—may reduce the vital capacity markedly and, as may be readily understood, that reduced vital capacity would favor pulmonary complications and atelectasis. There is a great variation in the vital capacity of the so-called normal patient. A laborer may have a tremendous vital capacity while that of a thin housewife may be quite sub-normal. Whether one or the other of these types is more prone to atelectasis we are not certain, but there is no doubt that if atelectasis occurs, the symptoms of the patient with the sub-normal vital capacity are much more acute.

Pre-operative medication may affect the respiratory rate, the cough reflex, the bronchial secretion and the intra-pleural pressure—all of which may be important factors abetting the production of atelectasis. Brill and Leake[12] have shown that atropin, for example, causes a definite swing of the intra-pleural pressure to the positive side. (Fig. 19.) Writers from the earliest times have noted that atelectasis occurs very commonly in children. It is worth while to consider whether the relatively less negative intra-pleural tension in the young does not favor this condition.

Operative.—At the time of operation the position of the patient on the operating table and the length of time of the operation may favor a collapse. It has been shown that when a patient is flat, or slightly Trendelenburg, his vital capacity is definitely reduced.[21] We also know that if one side of the chest is dependent, secretions tend to collect on that side. Lipiodol observations have permitted us to follow the course of this filling within the lung. (Figs. 20 and 21.) Scott and Joelson[76] report an interesting case of a massive collapse occurring in the dependent lung of a nephrotomy case. Some time later, when the other kidney was operated upon, this same patient developed an atelectasis, this time in the opposite lung which was the dependent one.

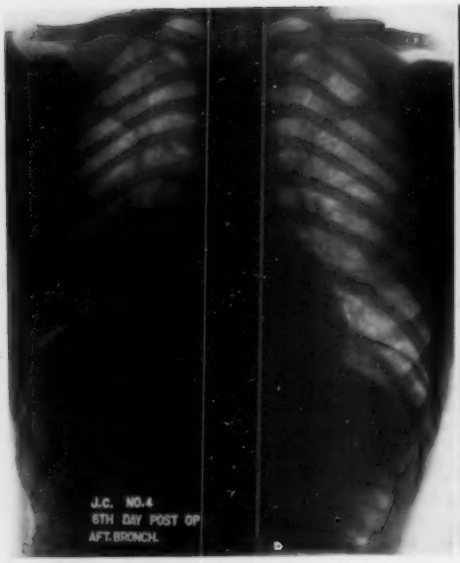

FIG. 40.—Same patient as Fig. 39 following bronchoscopy. (See page 829 for case report of J. C.)

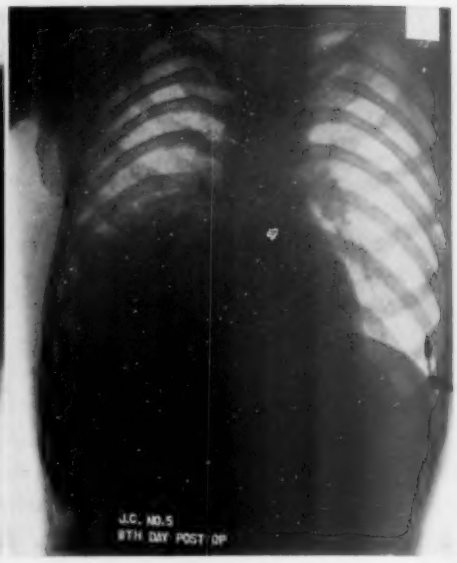

FIG. 41.—Same patient, J. C. (see page 829 for case report), following second bronchoscopy. The film before bronchoscopy was exactly similar.

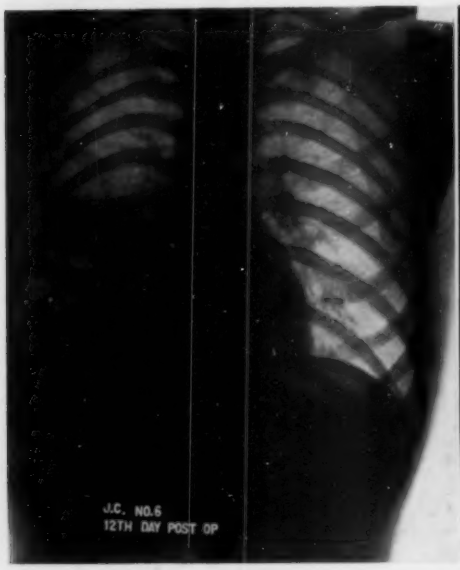

FIG. 42.—Patient, J. C. (see page 829 for case report), showing beginning clearing of right chest.

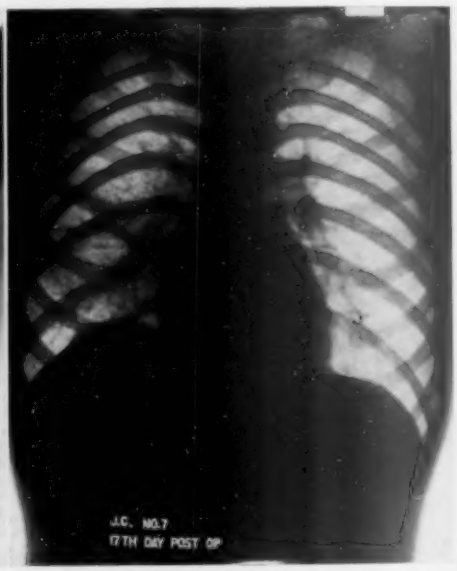

FIG. 43.—Same patient, J. C. (See page 829 for case report.) Chest practically normal.

There is no definite evidence that the length of time that the patient is on the operating table has any marked effect on the production of atelectasis.

FIG. 44.—Pre-operative film of B. V. (See page 830 for case report.) Essentially normal.

FIG. 45—Film, second day, following gastric resection showing an almost massive atelectasis of the left lung—B. V. (See page 830 for case report.)

In our cases of gastric resection atelectasis occurred with great frequency. Whether or not this was due to the length of time of the operation or to other factors we are unable to state. In general, it has been claimed that upper abdominal operations have a greater incidence of atelectasis, but our figures do not bear this out, with the exception of gastric resection as noted.

FIG. 46.—Chest film of B. V. (see page 830 for case report) three days post-operatively showing clearing of the left lung following CO_2 inhalations and postural changes.

It is difficult at this time to judge whether the anæsthetic plays any important part since most authors agree that the complication is as frequent under all anæsthetics. In the series we have been reporting, spinal anæsthesia was used in 62 per cent. of the cases. So far as we can judge, the incidence was not diminished.

The surgical procedure itself may have a marked effect on the physiolog-

ical process going on in the chest. The effect on the respiratory rate, for example, when traction is put on the mesentery has been noted by all surgeons. Little attention, however, has been paid to the changes which take place in intra-pleural pressure which may play quite a part in favoring chest complications. Pressure on the abdomen, evisceration and traction of various organs and the mesentery have a marked effect on the respiratory rate and intra-pleural pressure as shown by Brill and Leake.[13] (Figs. 22, 23 and 24.) A fuller report on this work is to be made later.

Post-operative.—That the post-operative position of the patient may be a factor in the production of atelectasis is generally agreed, as is also the necessity for frequent postural changes. The possibilities are, to keep the patient flat in bed; head dependent and feet elevated; or in the Fowler position. There are two important effects to consider. The *first* is the effect of the patient's position on his freedom of respiratory movements and vital capacity. It has been amply demonstrated that with the head dependent, the vital capacity is greatly reduced and respiratory movements are impeded. The same is true to a lesser degree when the patient is flat in bed. With the patient in the Fowler position there is probably the least impediment for free respiration and the vital capacity is increased. These points, therefore, favor keeping the patient in the Fowler position post-operatively whenever possible and, of course, changing the position frequently as mentioned. The *second* is the effect of the patient's position on intra-bronchial secretions. A careful study has been made on intra-bronchial drainage by the use of lipiodol in the human being. Faulkner[18, 19] has demonstrated that pulmonary secretions may easily pass from one lung to another or may gravitate within one lung to different lobes. Postural drainage has long been used in the treatment of lung abscess, but we do not feel that it has been employed in keeping with the principles of internal drainage. By careful study of the anatomy of the bronchial tree we have worked out the different positions which should drain various lobes of the lung into the trachea immediately after operation.

The relation of posture and spilling is shown in upper lobe atelectasis and suppuration. With the patient lying upon his back, all the physical findings are limited to the upper lobe, whereas the lower lobe is clear. As soon as the patient assumes the erect position and deep breathing exercises are instituted, the abnormal signs in the upper lobe may clear and appear in the lower lobe. We have interpreted this as a mechanical spilling from higher to dependent areas. This spilling is dependent on the patency of the bronchus, posture of the patient, the relative position of the bronchial openings and the viscosity of the intra-bronchial secretions.

Churchill and McNeil,[23] Powers[68] and others have shown the marked diminution in vital capacity following certain operative procedures. Muller, Overholt and Pendergrass[58] have beautifully demonstrated effects on chest expansion, elevation of the diaphragm and limitation of the diaphragmatic movements in these cases. In our clinic we have confirmed most of these findings and have been somewhat interested to note the time interval it takes

for this diminished vital capacity to return to normal. In many cases it is found to be three months post-operatively. All these factors favor any pulmonary complication, as well as atelectasis in particular.

In the post-operative treatment of the patient the effect of drugs on the respiratory mechanism may be again mentioned. Their possible action has been discussed. Other procedures, such as any that would impede respiratory movements, vital capacity, or the ease of expelling bronchial secretions must all be considered as favoring a pulmonary complication.

The part played by entrance of air into the peritoneal cavity and its collection under the diaphragm is not well understood. That such collections may be quite large in amount is shown in Fig. 25, No. 1. Whether the air

FIG. 47.—Film of B. V. (see page 830 for case report) seventh day post-operatively showing recurrence and complete atelectasis of left lung. (Same as Fig. 9.)

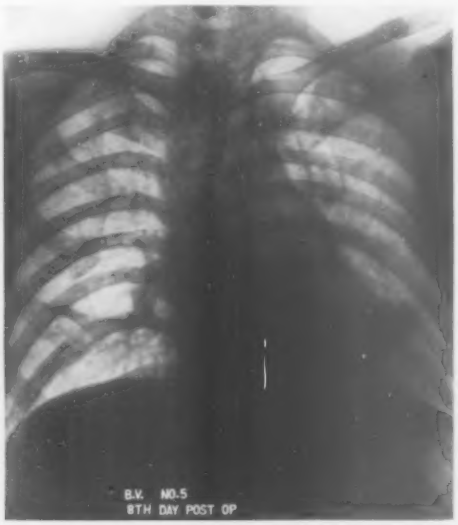

FIG. 48.—Chest film of B. V. (see page 830 for case report) following further treatment with CO_2 inhalations and postural changes. Note marked clearing in comparison with Fig. 47.

has an irritant or somewhat paralyzing effect, we cannot say at present. The diaphragm, however, is elevated. Acute dilatation of the stomach and bowel distention may also have a marked effect on the respiratory mechanism. Fig. 26, No. 1, is a Röntgen-ray of a little girl following an appendicitis operation who had signs of dulness, rales and diminished breathing at both bases. A diagnosis of atelectasis was considered. Note the height of the diaphragm and the rotation of the heart. Following an enema the chest picture entirely cleared, and physical signs were essentially normal. (Fig. 27, No. 2.) Another example of this phenomenon in an adult may be seen in Figs. 28 and 29, Nos. 1 and 2, which show the same effect on the diaphragm and the heart. Note the marked bowel distention. This patient's chest signs also cleared following colonic flush.

The changes produced in the intra-abdominal tension by these complications and their effect on intra-pleural tension is not clear. However, these pressure changes may also affect pulmonary physiology.

*Bronchoscopic observations.**—The use of the bronchoscope in the diagnosis and treatment of atelectasis has greatly extended our knowledge of this disease. Its value in diagnosis and treatment cannot be overestimated. Leopold[50] first suggested its use in this disease and the first reports by Jackson and Lee[43] of the cure of atelectasis by aspirating the plug were dramatic.

Our bronchoscopic observations[16] in cases of proven atelectasis, broadly considered, can be grouped into three main types of cases: first, there are those in whom the bronchus is found obstructed, either with a plug or the characteristic tenacious sputum, to be described; secondly, there is another group in whom there is no complete obstruction, but a rather profuse, purulent secretion, not so viscid as the typical tenacious type; and, thirdly, we may find practically no secretion at all. In this latter type, there is always the possibility that during the process of preparing for bronchoscopy the plug has been expelled. The unusual finding of a practically complete occlusion of the right main bronchus by an œdematous swelling of the mucous membranes has been mentioned.

The characteristic sputum in these cases is a thick, pearly, yellow, gelatinous and tenacious material which, when placed in a container, adheres firmly to it even when inverted. Such material, we believe, produced the more extensive types of atelectasis. The sputum may also be thinner in consistency and purulent, which is probably the type that may produce scattered, or patchy, atelectasis. Other cases have practically no sputum. Further observations will be mentioned under prevention and treatment.

Prevention.—The pre-operative, operative and post-operative factors which may favor the occurrence of atelectasis have been discussed. The use of CO_2 induced hyperventilation, and postural changes as a prophylactic measure deserve special mention. The administration of CO_2 immediately following the operation for the purpose of de-anæsthetizing the patient was first suggested by Henderson, Haggard and Coburn,[39] in 1920.‡ They claimed that besides the above action various physiological processes, especially the vasomotor apparatus, were rapidly restored to normal by this procedure. Although Reimann, Bloom and Reimann[69] disagreed with them, the weight of evidence seems to favor Henderson's contention. Little attention, however, was paid to this work up to the past three years. In 1927, Sise, Mason and Bogan[80] suggested the use of CO_2 inhalations and various postural changes as a prophylactic measure to lessen the incidence of post-operative pneumonia. This report was published in June, 1928. At the same time a report by Scott and Cutler[77] appeared on the use of an exactly similar procedure as a prophylactic measure against massive atelectasis and one of us[17] had independently suggested it. Scott[77, 78] reports a reduction in the incidence of

*Bronchoscopic observations were made by William B. Faulkner, Jr., and by A. L. Brown.

‡ In a personal communication from Yandell Henderson attention is drawn to the fact that the therapeutic use of CO_2 inhalations was suggested by him in 1905. Henderson, Y.: Aeapnia as a factor in shock. Brit. Med. J., Vol. ii, p. 1812, 1906.

massive atelectasis from 0.6 per cent. to 0.25 per cent. by the use of such prophylactic measures. More recently, Henderson, Coryllos[41] and their associates report excellent results with the use of CO_2-induced hyperpnœa, not only in prophylaxis, but also in the treatment of post-operative atelectasis and pneumonia in general.

We have administered CO_2 on the operating table after all inhalation anæsthesia. Following other types of anæsthesia, such as local and spinal, the procedure was not constantly carried out. All operative cases during the past year have been given CO_2 inhalations without oxygen, three to four times a day for the first three or four days following operation. It is useless to compare this series with that of previous years since chest complications had never been so carefully looked for and, by comparison, therefore, we apparently have an increased incidence of this sequela. In this connection, it is interesting to mention again the recent report of Van Allen and Adams, who found, in the experimental animal, that straining respirations favored the production of atelectasis when the bronchus was plugged, while with quiet breathing they were unable to produce the lesion. Henderson,[40] on the other hand, says: "Shallow breathing strongly predisposes to bronchial obstruction and thus to atelectasis in the obstructed areas. Contrariwise, deep breathing tends to distend the lungs and to reopen areas of atelectasis. The natural stimulant to deep breathing is the carbon dioxide produced within the body."

Bronchoscopically, we have noted that the administration of CO_2 produced: (1) increase in the rate and depth of respiration; (2) production of violent movements in the tracheo-bronchial tree and alterations in the shape of the lumenæ of its branches, thereby tending to free adherent mucus; (3) induction of a distinct blanching of the mucous membranes of the trachea and bronchi.

If CO_2 is administered with the patient in the proper position, the resultant widening of the bronchus permits the secretions to spill from minor bronchi to major ones. This frequently produces a coughing paroxysm, even when the major bronchus has been thoroughly cocainized. With this paroxysm the patient tends to expel the secretions.

We believe that CO_2 inhalations may affect the patient in one of two ways. He may either be markedly improved or made decidedly worse. The difference in the outcome depends on the posture assumed by the patient during the administration of the CO_2 inhalations. If the patient is placed in such a position that the involved area is uppermost and the bronchial opening leading from it is dependent, the CO_2 inhalations lead to a satisfactory drainage and expectoration of secretion, whereas, similar inhalations, with the involved area dependent and the bronchial opening uppermost, will interfere with adequate drainage and expectoration and permit the secretions to run deeper into the lung.

Archibald and Brown[3, 15] have noted experimentally that cough and violent respiratory effort may tend to drive fluid substances, similar to

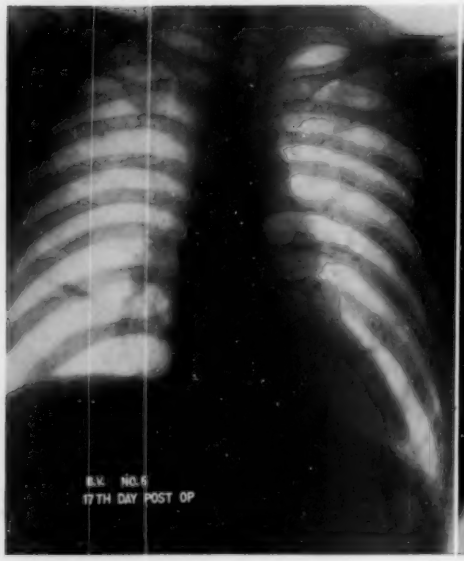

FIG. 49.—Chest film of B. V. (See page 830 for case report.) Return of chest to normal.

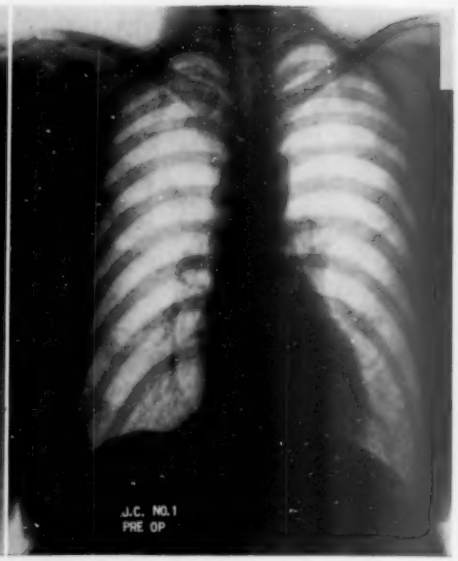

FIG. 50.—Pre-operative film of J. C. (See page 831 for case report.)

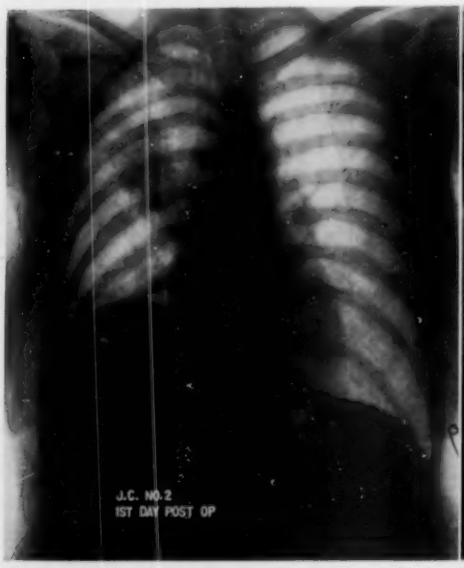

FIG. 51.—Film of same patient as Fig. 50. (See page 831 for case report.) First day post-operatively showing atelectasis in the right lung with peculiar triangular shadow leading from the right hilus.

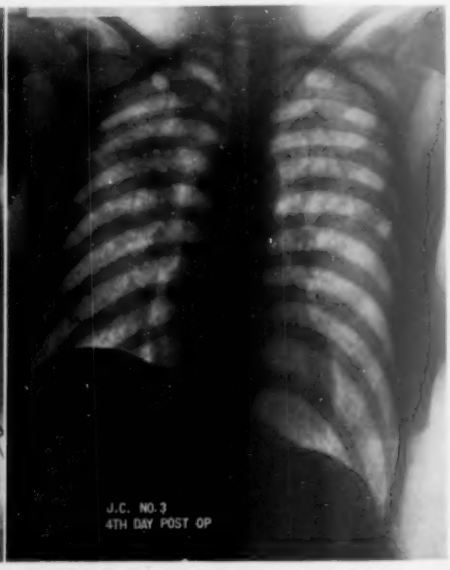

FIG. 52.—Film of same patient as Fig. 51 showing some clearing of triangular shadow but no decrease in cardiac displacement or height of diaphragm.

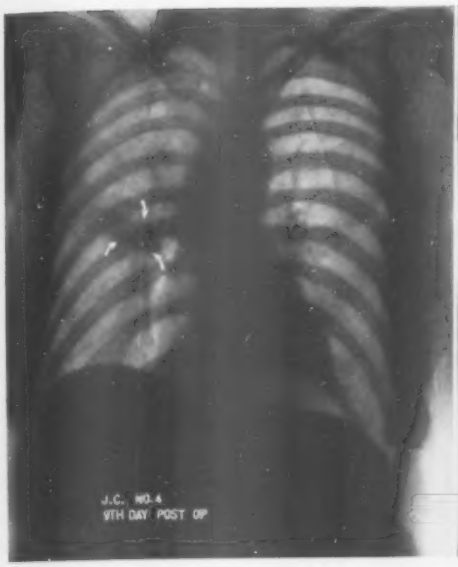

FIG. 53.—Same patient, J. C. (see page 831 for case report), showing return of diaphragm and heart toward normal relations, but change in the triangular shadow which is to become a lung abscess.

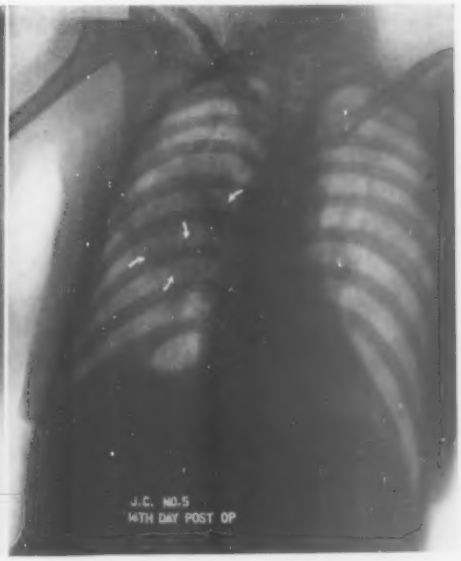

FIG. 54.—J. C. (see page 831 for case report) showing definite Röntgen-ray evidence of lung abscess with heart and diaphragm returning to normal position.

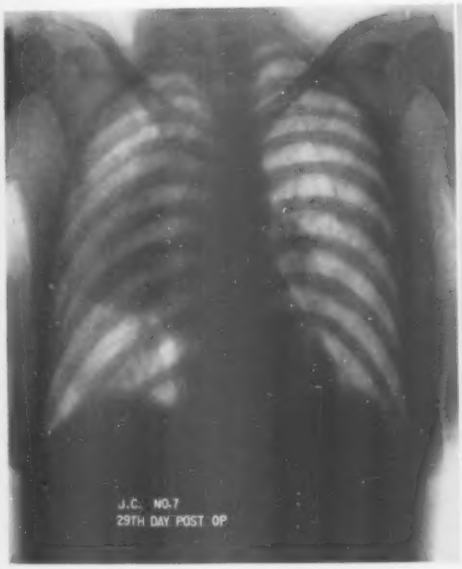

FIG. 55.—Same patient, J. C., four days before death, showing the extent of the lung abscess. The intervening plates are omitted.

FIG. 56.—Same as Fig. 55. Lateral view. Note location of the abscess in the upper part of the lower lobe and fluid level.

iodized oil, deeper into the pulmonary tree. This does not take place with a heavier substance, such as thick, tenacious sputum. This action of cough, if it can be applied to the human, is of great importance. A successful outcome with CO_2 inhalations and postural changes is, therefore, dependent on: (1) knowledge of the anatomy of the tracheo-bronchial tree; (2) the relative position of the various bronchial openings; and (3) the course of the bronchial stems.

The post-operative posture of the patient has been sufficiently discussed. It is only necessary to add that in certain cases where there is profuse bronchial secretion during and immediately after the operative procedure, we have found it advantageous to place the patient in the Tredelenburg position for from one-half hour to an hour and allow the secretions to drain out. It is worth while to consider here whether it would not be of value to employ bronchoscopic aspiration immediately after operation in cases where there has been profuse bronchial secretions. In two cases where the lungs were flooded with secretion and blood this procedure was carried out (by William B. Faulkner, Jr.), and these patients developed no post-operative lung complications.

Treatment.—The treatment of this condition is in the experimental stage. According to some authors,[28, 37] in cases of massive collapse, symptomatic relief may be obtained by the introduction of air into the pleural cavity on the affected side. As Bowen[8] states: "Pneumothorax is mentioned here, only to condemn it." While it is true that this procedure may allow the displaced mediastinum to return to its normal position due to the relief of the increased intra-pleural tension, it does nothing to relieve the pulmonary pathology as we understand it.

As carefully as the older writers studied atelectasis, the displacement of the heart and mediastinum was not recognized by them. Although Bowen gives Stokes[82] credit for having noted mediastinal displacement, a careful perusal of his treatise makes us believe the condition which he calls "the vesicular emphysema of Laennec" is not atelectasis. Samuel West,[85] in 1908, first remarked on the marked displacement of the heart in a case of collapse of the lung in a girl suffering from plastic bronchitis. Pasteur, in his later papers, recognized the importance of the heart displacement, but at first was somewhat confused as to its mechanism. Elliott and Dingley proved the cardiac displacement to the affected side by röntgenograms and adequately explained it by concluding that the intra-pleural tension must be greatly increased on the involved side. The measurements of Elkin[28] and others[37] since that time show their deductions to have been correct.

Sante's report has been mentioned previously. Scott, Cutler, Bowen and others comment favorably on his suggestion of rolling the patient back and forth on the uninvolved side. We have had a good deal of success using this procedure, at times somewhat more elaborated with the principles of intra-bronchial drainage, mentioned above, and in combination with CO_2

inhalations. An excellent example of the results that may be obtained with this type of treatment is shown in the following case.

M. A., male, aged forty-nine, had a right-sided hernioplasty under spinal. His temperature, pulse and respirations had been normal on the fifth day post-operatively, when he suddenly developed a fever of 102.8°. The respiratory rate was 28, and he began to raise thick, tenacious, green, purulent sputum. Fig. 30, No. 1, is the chest film taken on that day. He was given CO_2 inhalations every two hours and various postural maneuvers were applied. On the following day his chest film (Fig. 31, No. 2), was essentially normal.

Not all cases, however, respond so promptly to this type of treatment. Certain ones, in spite of vigorous treatment with CO_2 and postural changes, clear very slowly, while others (in a control series from another hospital) may recover in less than a week with no treatment. However, in general, there is no doubt that this type of treatment shortens the convalescent period and may prevent complications.

The results of bronchoscopic aspiration in atelectasis, as has been stated, may be very marked. The series of films of P. M. (Figs. 32, 33 and 34, Nos. 1, 2, and 3), and the series of W. O. (Figs. 35 and 36, Nos. 1 and 3), demonstrate what a marked change may take place within a few hours in a case of collapse of the entire right lower lobe or part of it. Figs. 3, 4, 5 and 6, given above, are also examples of marked clearing following this procedure.

There are certain types of cases that will recur under any form of treatment. This is especially true if they are uncoöperative, as was the following patient.

J. C., male, aged twenty-seven, two days following an appendectomy under spinal anæsthesia for acute appendicitis developed a cough, some fever, increased pulse rate and a respiratory rate of 35. He brought up large amounts of thick, purulent, tenacious sputum. Physical examination showed dulness, absent or diminished breath sounds and moist crepitant rales at the right lower chest. Heart and trachea were displaced to the right. The film taken on the next day (Fig. 37, No. 1) confirmed these findings. He was immediately put on CO_2 inhalations and postural changes. Röntgen-ray film, taken a short time afterward (Fig. 38, No. 2), showed some clearing just above the diaphragm and beginning return of the displaced heart and mediastinum. However, on the following day (Fig. 39, No. 3), his findings were as bad as, or worse than, at the onset. In the next two days he showed no improvement, so it was decided that bronchoscopy was indicated.

The bronchoscopic report is as follows: "There is a general tracheal bronchitis, marked with placques of pus in the trachea; two large gelatinous plugs to the left side of the carina, each the size of a bean. Similar types of pus, but of smaller bulk, were encountered in both upper lobe bronchi and at scattered areas throughout the other bronchial openings. The minor tertiary divisions of the posterior and vertebral bronchi contained pus of a similar nature."

Immediately after bronchoscopy there seemed to be some improvement. (Fig. 40, No. 4.) The patient, however, continued to do poorly. On the eighth day, post-operatively, it was decided to bronchoscope him again. The report is as follows: "Entire tracheo-bronchial tree of an extraordinary fiery red color, equally as red as on the original examination. The right posterior minor bronchus has a very definite, thick,

gumous, gelatinous plug occluding its opening. This plug was not dislodged on coughing which was associated with cocainization or the passing of the bronchoscope. We removed the plug mechanically. The vertebral tertiary minor bronchus was not plugged. Even though no pus was encountered in the middle lobe on first examination, at this time, following the application of CO_2 and adrenalin, several good-sized chunks of pus were forced out on coughing."

The Röntgen-ray film, before and after bronchoscopy, showed no change in the condition (Fig. 41, No. 5), and the question arose as to whether or not a pneumonia had been ingrafted in this case. From this time on the patient cleared very slowly. (Figs. 42 and 43, Nos. 6 and 7.)

This case seems to be one of atelectasis (as shown by the height of the diaphragm on the right and the cardiac displacement) on which a pneumonia was ingrafted and, perhaps due to the uncoöperative type of patient, was not helped by any type of treatment.

A similar case, but one that did not have bronchoscopic treatment, is shown in the next series of plates.

B. V., male, aged forty-seven, had an extensive resection of a large callous ulcer on the posterior wall of the stomach under spinal, gas and ether anæsthesia. His preoperative chest film (Fig. 44, No. 1) was essentially normal. On the second day, post-operatively, he developed a cough and brought up small quantities of thick, yellow phlegm. His temperature, pulse and respirations were only slightly elevated. His film on that day (Fig. 45, No. 2) showed an atelectasis on the left side with marked displacement of the heart and mediastinum. He was put on our routine treatment of CO_2 inhalations and postural changes and on the following day was markedly improved (Fig. 46, No. 3). On the seventh day, post-operatively, his sypmtoms recurred and the film taken on that day (Fig. 47, No. 4), showed practically a massive collapse of the left lung. A consultation was held to decide whether bronchoscopy should be done at this time but, on account of his good condition and lack of dyspnœa, it was decided to continue the use of CO_2 inhalations and postural changes. He brought up a large amount of thick sputum under this régime and felt markedly improved. The plate on the next day (Fig. 48, No. 5), showed marked clearing and from this time the lungs gradually returned to normal (Fig. 49, No. 6).

To summarize our present opinion as to treatment, we believe that the CO_2-induced hyperventilation, combined with frequent postural changes, according to the principles of intra-bronchial drainage, should be used as soon as the complication is recognized. A large number will clear up rapidly under this régime. If they do not and if the symptoms are at all acute, or if from the character of the sputum and the physical findings there is evidence that there is a plug, or tenacious sputum, we believe bronchoscopy is indicated. We have never had a bad result from bronchoscopy and believe that this procedure in the hands of a well-trained man is without danger or ill effects.

Prognosis.—All observers have noted that many of these patients get well without treatment. The scarcity of autopsy reports in this complication is due to this low mortality. We have not had a death in an uncomplicated case of atelectasis.

The case of J. C., noted above, demonstrated that a pneumonic process may be ingrafted on an atelectatic process. An instance of lung abscess complicating an atelectasis is described in the following report:

J. C., female, aged thirty-seven, had a curettage and laparotomy for sterilization under spinal and ether anæsthesia. The pre-operative plate (Fig. 50, No. 1), was essentially negative, although she was supposed to have had tuberculosis at the right apex. Fig. 51 (No. 2), first day post-operatively, taken not because of respiratory symptoms but in our routine study, showed an irregular triangular shadow radiating from the right hilus toward the apex with irregular mottling throughout the right base. There was marked elevation of the right diaphragm with the heart drawn to the right and ribs contracted. The triangular shadow was diagnosed as an infarct but, in view of subsequent events and the marked displacement of the diaphragm and heart, we believe this to be an atelectasis of the apex of the right lower lobe. At this time she had no sputum. T. 38°, P. 110, R. 32. She was treated for atelectasis with CO_2 inhalations and postural changes, but was very uncoöperative. On the fourth post-operative day (Fig. 52, No. 3), the triangular shadow was decreased in extent and she seemed to be improved. After this time the patient became worse and bronchoscopy was suggested and refused. She continued having an irregular fever and elevated pulse and cough with little sputum. The plate taken on the ninth post-operative day (Fig. 53, No. 4), showed the heart and diaphragm returned to normal position, but a new process had started. The arrows point to a beginning abscess forming in the upper portion of the right lower lobe. At this time T. was 38.8°, P. 80, R. 24.

By the fourteenth post-operative day, the process was much more marked and the abscess cavity seemed to have extended. At this time the patient was beginning to have foul abscess sputum. Temperature rose to 39° every afternoon. She refused any type of treatment. Figs. 54 and 55, Nos. 5 and 7, show progress of the abscess. The lateral view (Fig. 56, No. 8), taken shortly before death, gives a better idea of the location and extent of this abscess.

On the thirty-third day post-operatively, the patient suddenly developed a coughing paroxysm, became very dyspnœic with many coarse, gurgling rales throughout both chests. Before anything could be done for her, she expired. Death, apparently, was due to the abscess breaking and flooding the bronchial tree.

Repeated examinations of her sputum throughout her illness always showed streptococcus viridans predominating and a few colonies of staphylococcus aureus and staphylococcus albus. There were no elastic fibres, tuberculosis bacilli or spirochetes. Guinea pig was inoculated and was negative for tuberculosis. It is interesting that ten months previous to operation she had had her sputum cultured three times. Each time streptococcus viridans and a non-hemolytic streptococcus was found. A vaccine was made of this with which she was treated for asthmatic attacks. Unfortunately, at post-mortem the abscess was not cultured, but the report on the stained abscess wall is as follows: "Bacteriological examination of tissue from abscess wall shows a few scattered Grampositive cocal formations, apparently diplococci."

The post-mortem report (Dr. G. Y. Rusk) is as follows:

"*Anatomical diagnosis.*—Abscess of upper portion of lower lobe of right lung, *apparently of bronchogenic origin.* Irregular pneumonic consolidation with beginning organization and interstitial pneumonia in adjacent regions. Purulent bronchitis in lower lobe of left lung. Purulent tracheitis." (Remainder of this portion of report is not significant.)

Gross examination.—The left lung is essentially negative except for some compensatory emphysema and pus and cloudy œdema on the bronchi. The right lung shows chronic pleural thickening and interlobular adhesions. The upper lobe is negative. "On section of the lower lobe the upper half presents an irregular network of septa dividing the tissue between a number of pus-containing cavities of varying size. The tissue forming the walls of the cavities presents varying degrees of consolidation and some œdema; some areas are opaque, yellowish gray, as if containing fat, others

hyperemic and beefy-looking, apparently beginning organization. Dissection of the bronchi in this neighborhood again shows a hyperemic, velvety surface with purulent exudate. The septa between the pus cavities in part appear relatively firm as if they represented to some extent bronchiectatic cavities. The pneumonic consolidation adjacent to the abscesses forms an irregular layer about two centimetres thick along the upper border of the lower lobe and consists of irregularly disseminated areas of consolidation throughout most of the lateral and posterior portion of the lower lobe.

"*Microscopic examination. Lungs.*—Sections from wall of abscesses show a lining for the most part consisting of a fibrinous exudate containing a few polymorphonuclear leucocytes and mononuclear cells. At a few points bits of bronchial epithelium are encountered and rarely some of this is converted into a flat squamous type of cell. Beneath the fibrino-purulent exudate the tissues show a variety of pictures. Many of the alveoli contain contracted masses of fibrin about which there are mononuclear cells of varying types, some large cells of epithelial type from large fat-containing cells and an occasional lymphocyte. Some of the fibrin tangles are penetrated by vessels and young connective tissue cells. The alveolar walls are œdematous, thickened, showing varying amount of infiltration with lymphocytes and plasma cells and undifferentiated mononuclear cells together with a varying amount of overgrowth of young fibrous tissue elements. This organizing and interstitial pneumonic process extends widely in the tissue. *It appears that the process is of bronchogenic origin rather than an embolic process originating in the parenchyma of the lung with secondary openings into the bronchi.*"

This we believe to be a case of lung abscess ingrafted on an atelectasis. The autopsy strongly supports this, as do the Röntgen-ray studies. Whether the complication was due to the fact that this atelectatic area was never properly drained and became secondarily infected with a virulent organism, or whether there might have been a secondary infarct in the atelectatic area which made a fertile field for a virulent organism, we cannot say. Churchill[22] has suggested that multiple emboli might complicate an atelectatic area and favor a pneumonic process being ingrafted on it. Also Holman and Mathes[42] have been able to produce pulmonary abscess with sterile emboli in the presence of previous infection, either pulmonary or systemic.

In general, the prognosis of the uncomplicated case of atelectasis is excellent. The majority recover, treated or not. When complicated by a virulent pneumococcus infection or other organism which may produce lung abscess, gangrene, *etc.*, the prognosis may be serious. Bilateral massive atelectasis of any extent, unless immediately relieved, will, of course, cause death. Reports of such cases have been mentioned.

SUMMARY AND CONCLUSIONS

1. The predominating post-operative pulmonary complication is atelectasis. This may be of any extent, from involvement of very small portions of pulmonary parenchyma to a whole lung or both lungs.

2. Bronchial obstruction is the most important single factor in the production of atelectasis, and with the relief of the obstruction the lung tissue reinflates. Pre-operative, operative, and post-operative factors which may aid the formation of this lesion have been discussed. Whether these factors,

Statistics on Post-Operative Complications in Major Operations

Anæsthetic	No. of Operations	Per Cent of Operations	Type of Complication					
			Atelectatic	Per Cent	Pneumonic	Per Cent	Embolic	Per Cent
Spinal	232	62	12—5.1%	5.7	6	2.6	2	0.9
Spinal and Gas or G. and E.	49		4—8.2%					
Gas–O	107	23	2	1.9	1	0.9	0	
Ether	42	9.2	3	7.1	2	4.8	0	
Local	18	4	1	5.6	0		0	
Miscellaneous (Amytal, avertin and unknown)	8	1.8	0		0		0	
Totals	456	100.0	22	4.8	9	2.0	2	0.4

Total pulmonary complications = 7.2 per cent
Of all pulmonary complications atelectasis = 67.0 per cent

These complications do not include patients who post-operatively had signs of scattered atelectasis or congestive areas in the lungs of an evanescent nature, but which did not show on the Röntgen-ray plate. Two of the cases classified under pneumonia were hypostatic congestion and might be regarded as atelectatic in nature due to accumulated secretions. In the whole series there were six deaths; three in the pneumonia group and three from the atelectatic group. Of the latter, one was an old lady of eighty whose atelectasis had cleared but who died a month post-operatively very suddenly; the second was a man who developed hemiplegia and the third was a case of lung abscess described in the text.

either alone or through a reflex, may initiate the process and secondarily produce obstructing secretion, we are unable to state.

3. Bronchoscopically, we noted four types of findings in atelectasis: (1) the presence of an obstructing plug or characteristic tenacious sputum; (2) a profuse, purulent secretion; (3) no secretion in the bronchi; (4) one unusual case of local bronchial œdema.

4. In prophylaxis and treatment, the importance of applying the principles of intra-bronchial drainage in the posture of the patient, in combination with CO_2 inhalations, was discussed. The use of bronchoscopic aspiration in prophylaxis, as well as in treatment, was suggested.

5. The prognosis of this post-operative lesion, unless complicated by a secondary process, is excellent.

6. We do not believe that all post-operative pulmonary complications, excluding embolic types, are of the same nature. From clinical, Röntgen-ray and bronchoscopic observations, there seems to be one type that is more like lobar pneumonia. An example of this type is given.

Doctor Brunn wishes to express his thanks to Drs. William B. Faulkner, Jr., A. Lincoln Brown and Maurice L. Lubin, staff members of the Clinic on Thoracic Surgery at the University of California Medical School, who have coöperated both in the clinical

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THE TREATMENT OF FRACTURES BY OPEN OPERATION AND DIRECT FIXATION

A CRITICAL SURVEY OF AN EXPERIENCE OF TWENTY YEARS, AND MORE PARTICULARLY OF TWO CONSECUTIVE FIVE-YEAR PERIODS

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The year 1880, which saw the foundation of the American Surgical Association, saw also the publication by Sir William Macewen, my illustrious predecessor, of his book on "Osteotomy."[1] Even prior to that year Macewen had been interesting himself a great deal in the surgery of bone, a subject which I have often thought was nearer to his heart than many of his other scientific interests. At almost every stage in his professional career, and whatever other lines of work might more particularly engage his attention for the time being, problems connected with the development and repair of bone constantly intrigued him.

I need not here refer in any detail to the history of the transplantation of bone, nor to the classical case of heteroplastic transplantation of bone described by Macewen—the case operated on in 1878 by him originally, and the progress of which was followed up by him for over thirty years. Nor need I do more than refer to the great periosteum controversy in which Macewen delighted to take part—save to remind you that there are few today who would dispute the essential justice of Macewen's contention, namely, that the function of the periosteum was not osteogenic, but limiting, protecting and vascular.

Macewen's monograph on "Osteotomy" was based on an extensive series of observations and operations which he had been carrying out for a number of years upon the varying osseous deformities of rickets, and upon the surgical treatment of these. He had already made several contributions to the literature of the subject, and he had communicated his views and results to the profession, in the course of various discussions in medical societies, and by several communications in medical journals of the day. His monograph dealt also, in a comprehensive way, with the etiology and pathology of rachitic osseous deformities of the lower limbs. It remains a classic.

The method of osteotomy which Macewen described—particularly supracondyloid osteotomy of the femur for the treatment of genu valgum—soon established itself not only as sound and safe, but as the operation of choice in the treatment of genu valgum. I have described elsewhere[2] the great personal triumph achieved by Macewen at the discussion in the section of surgery at the "Congrès Internationale des Sciences Médicales" held in Copenhagen in 1884, when other surgeons such as Ogsten, Chiene, and

Bryant, with one accord admitted the superiority of Macewen's method and technic.

I make this allusion to Macewen's monograph on "Osteotomy" because the mass of clinical material, the results of which he was able to present, implied an adventure into a new surgical realm which, but for the discoveries of Lister, would have been hazardous in the extreme, if not indeed entirely impossible. It was rendered possible by, and only by, the practical application of the principles of antiseptic surgery. When one remembers that the 835 osteotomies carried out on 557 limbs of 330 patients were performed almost without suppurative mishap—in only eight cases did wound infection occur, and in only one did it lead to serious trouble—and that practically all were dealt with in the very earliest days of the Listerian régime, one cannot fail to realize that the record was remarkable.

It occurred to me that it might not be inappropriate on this occasion, when you have been good enough to invite me to join with you in the celebration of the fifteenth anniversary of the foundation of your Association, were I to choose as the subject of a short paper, another branch of the surgery of bone in which, even as in this particular field dealt with by Macewen, the principles and practice of antiseptic, or aseptic, surgery, are of paramount importance. I refer to the treatment of fractures by open operation.

During the last thirty years, and more particularly during the last twenty years, the operative treatment of fractures and the use of internal or direct methods of fixation, to the inception of which we owe so much to the enthusiastic advocacy of Sir Arbuthnot Lane, have been widely practiced and very widely discussed. The literature of surgery has been full of communications on the subject, and in the earlier years particularly, there was waged a controversy marked by very wide divergence of opinion. Nowadays, I fancy, there is less disagreement as to the justification, at least in appropriate cases, for the operative treatment of fractures, though there still exists a certain number of stalwarts who would very narrowly limit its field of usefulness.

I am one of those to whom the passing of the years has brought, so far, no diminution of enthusiasm for the method, and to whom indeed there seems to present itself, as time goes on, an ever-widening field for its application.

My earliest contribution on the subject was at the discussion in the surgical section of the British Medical Association in London, in 1910.[3] As a comparative junior I had become convinced, even then, that open operation was justified, and indeed, greatly to be preferred in many cases of fracture of the long bones, to the older, more orthodox methods up to then in vogue. In my contribution in 1910, I boldly stated the grounds of my confidence, and I endeavored to lay down certain broad principles which should guide one to the adoption of open operation in cases of fracture. These broad principles, in my opinion, still hold good, but I would construe them now in a much more liberal and comprehensive way.

When the British Medical Association met in Glasgow in 1922, I pre-

sented a paper which still further proclaimed my belief in the treatment of fractures by open operation and internal fixation. It was entitled "A Five Years' Survey of the Routine Treatment of Fractures by Operative Methods."[4] In addition to the mere tabulation of cases and results during the five years' period with which it dealt, I described, in some detail, certain special procedures and modifications in the usual methods of direct fixation.

The publication of this contribution aroused, in many quarters, a good deal of comment, not always friendly and not infrequently somewhat severely critical. I have not been led, however, with the passing of the years and with continuing and increasing experience, to resile in any important respect, from the position which at that stage in my career I had taken up. Rather has my confidence in the method of direct fixation by open operation become reinforced and added to with ever-increasing experience.

The five years' period with which I dealt in 1922 was from the 1st May, 1917, to the 1st May, 1922. The cases included were from my own surgical unit in the Western Infirmary, Glasgow. Most of the cases were treated by myself throughout. A small number were dealt with by my junior colleague assistants who followed out the same general lines as myself. The five years' period was taken as representing a well-defined period of time, in a single surgical unit, for which we had full records and for the surgical control of which I was myself personally responsible. For the figures which we were able to present, my own reports and the reports of my junior colleagues were able fully to vouch. I shall refer to the results, and to the relative tables presently.

For the purpose of this further communication I propose to add a second five years' period immediately following the one referred to, namely, the five years from May 1, 1922, to May 1, 1927. I think it better to limit this fresh survey to five years in order to bring it into line with the other one, and to allow of the making of such comparisons as may be suggested. The three remaining years have not been included in the analysis, but if they had been, I am well aware that they would show no diminution in our interest in, and enthusiasm for, open operation.

The First Period of Five Years.—Within this period there were treated, in my wards in the Western Infirmary, 693 cases of fractures of all kinds, including skull, trunk and limbs. A general anæsthetic was administered in 459 of these. As a rule the anæsthetic was chloroform, and in a number of cases the anæsthetic was administered several times. The total number of administrations of a general anæsthetic in the whole series of fractures was 638. Out of the 693 cases open operation was carried out in 272, while in 421 no open operations were employed. Of the 272 cases submitted to open operation, the fragments were directly fixed by internal mechanical means in 103.

Stating these figures in percentages, therefore, it emerges that (1) open operation was carried out in 39.25 per cent. of the whole series; (2) some method of direct-mechanical fixation was employed in 14.86 per cent. of the

whole series; (3) direct fixation was employed in 37.86 per cent. of the cases treated by open operation. In other words, 62.34 per cent. of cases of open operation were dealt with without mechanical fixation.

These figures are presented in tabular form in Table I, reproduced here from my earlier paper. The table shows in the first column the total numbers for each year of fractures treated indoors. In the second column are given the numbers of cases submitted to open operation each year. The third column shows the number of cases in which direct fixation of fragments was carried out. The fourth column gives the percentage, for the year, of the whole series of the cases submitted to various types of direct fixation. In the fifth column are the percentages, for each year, of cases submitted to open operation in which direct fixation of some kind was employed.

TABLE I

First Series of Five Years

Cases of fracture of all kinds treated in Professor Young's wards in the Western Infirmary, Glasgow, in each of the five years, May, 1917, to May, 1922, showing the number of cases submitted to open operation, and the number treated by direct fixation—with relative percentages

Year	Total fractures	Submitted to open operation	Treated by direct fixation	Percentage of total fractures treated by direct fixation	Percentage of cases of open ope ation treated by direct fixation
1917–18.....	127	42	9	7.086	21.4
1918–19.....	135	49	11	8.14	22.4
1919–20.....	161	62	28	17.39	45.16
1920–21.....	152	58	19	12.50	32.76
1921–22.....	118	61	36	30.50	59.0

The Second Period of Five Years.—The figures for this period may now be given for comparison with the preceding. The total number of cases of fractures of all kinds within the period was 632. A general anæsthetic was employed in 405 of these, and the total number of administrations amounted to 526. Open operation was carried out in 267 cases out of the 632, while in 365 no open operation was done. Direct fixation was employed in 126 cases out of the 267.

Stating these figures also in percentages, we find that (1) open operation was carried out in 42.24 per cent. of the whole series (compare with 39.25 per cent. in the previous five years); (2) direct fixation was adopted in 19.93 per cent. of the whole series (compare with 14.86 per cent. in the previous five years); (3) direct fixation was employed in 47.19 per cent. of the cases treated by open operation (compare with 37.86 per cent. in the previous five years). In other words, in this series 52.81 per cent. of cases of open operation were dealt with without mechanical fixation. These figures are presented in tabular form in Table II, in which the various details for each of the five years are shown in the respective columns as in Table I.

The Ten Years' Period.—For convenience of comparison between the two five years' periods the two tables have been combined in Table III, a

TABLE II

Second Series of Five Years

Cases of fracture of all kinds treated in Professor Young's wards in the Western Infirmary, Glasgow, in each of the five years, May, 1922, to May, 1927, showing the number of cases submitted to open operation, and the number treated by direct fixation—with relative percentages

Year	Total fractures	Submitted to open operation	Treated by direct fixation	Percentage of total fractures treated by direct fixation	Percentage of cases of open operation treated by direct fixation
1922–23.....	119	61	38	32	62.3
1923–24.....	95	44	18	18.94	40.9
1924–25.....	135	56	22	14.81	39.3
1925–26.....	137	49	24	17.51	49
1926–27.....	146	57	24	16.44	42.1

general survey of which will show that, allowing for the casual variations in numbers of cases treated, and the inevitable differences in severity and extent of the fractures in different years, there has been arrived at a considerable degree of stabilization in respect of the numbers and percentages of cases submitted to open operation and to direct fixation.

TABLE III

Combined Ten Years' Series

Cases of fracture of all kinds treated in Professor Young's wards in the Western Infirmary, Glasgow, in each of the ten years, May, 1917, to May, 1927, showing the number of cases submitted to open operation, and the number treated by direct fixation—with relative percentages

Year	Total fractures	Submitted to open operation	Treated by direct fixation	Percentage of total fractures treated by direct fixation	Percentage of cases of open operation treated by direct fixation
1917–18.....	127	42	9	7.086	21.4
1918–19.....	135	49	11	8.14	22.4
1919–20.....	161	62	28	17.39	45.16
1920–21.....	152	58	19	12.50	32.76
1921–22.....	118	61	36	30.50	59.0
1922–23.....	119	61	38	32	62.3
1923–24.....	95	44	18	18.94	40.9
1924–25.....	135	56	22	14.81	39.3
1925–26.....	137	49	24	17.51	49
1926–27.....	146	57	24	16.44	42.1

It may be of interest also to give here the figures and percentages for the combined ten years' total number of cases. They are as follows: the total number of cases for the ten years amounted to 1,325. In the treatment of these a general anæsthetic was employed 864 times. The total number of administrations of a general anæsthetic in the treatment of the whole series of fractures during the ten years was 1,164. Out of the 1,325 cases open operation was carried out in 539, while in 786 no open operation was considered necessary or desirable. Immobilization of the fragments was secured by some method of direct fixation in 229 out of the 539 cases submitted to open operation.

Stating these figures also in percentages, therefore, we find that (1) open operation was carried out in 40.67 per cent. of the whole ten years' series; (2) direct fixation by some mechanical means was employed in 17.28 per cent. of the whole ten years' series; (3) direct fixation was made use of in 42.48 per cent. of the cases treated by open operation, leaving 67.76 per cent. of cases of open operation in which no form of internal mechanical fixation was employed.

Comparison with Earlier Figures.—In my previous paper (British Medical Association, 1922), I gave in tabular form, for comparative purposes, figures from the records of the Broadstone Hospital, Port Glasgow, of which I had the surgical charge during the nine years from 1907 to 1916. I reproduce this table here:

TABLE IV

Cases of Fracture of all kinds treated by Mr. Young at the Broadstone Hospital from 1907 to 1916

	1908	1909	1910	1911	1912	1913	1914	1915	1916	Total for 9 years
Total fractures.....	40	54	74	84	90	101	68	82	74	667
Treated by direct fixation.	1	2	6	5	8	1	8	6	3	40
Percentages.....	2.5	3.7	8.1	5.9	8.8	1.0	11.7	7.3	4.05	5.9

It will be seen from this table that, in the nine years' period immediately preceding the ten years' period under present consideration, I had been treating cases of fracture by direct fixation of some kind in about 6 per cent. of all fractures, while we have just seen that the percentage during the ten years' series has advanced to over 17 per cent. This may be taken as a very clear indication of the sincerity of our conviction that direct fixation by open operation has justified itself by its results. Otherwise, our continuance—nay, our increasing employment—of this method of procedure would be difficult to understand.

The Argument from Statistics and Experience.—As I pointed out in my earlier paper, the progressive increase in the proportion of cases dealt with by open operation, and by direct fixation, evinced our increasing confidence in the superiority of these methods over those previously employed. So now, in reviewing the second five years' period by itself, and after combining it with the earlier five years' period, there is clearly brought out the fact that our confidence has been maintained. One is entitled to assume, therefore, and to declare, that increasing experience has but served to stabilize and reinforce our confidence in the methods.

I have been accustomed to advance the further argument in favor of direct fixation by open operation that the continuance, and indeed, the increasing employment of it, can not be explained on the grounds of its simplicity or ease in execution. Indeed, it is far otherwise. Almost any operation for the direct fixation of fractures of the long bones may impose upon the operator and his assistants a considerable strain; may tax his and

their physical energy, endurance and ingenuity to the uttermost. The job is seldom a light or easy one. Any one who has witnessed many open operations of the kind, or who has ever taken part either as principal or assistant in such operations, will readily admit that all concerned must put a great deal of their physical strength and energy into the work; must, indeed, "sweat over it," in a very real and literal sense. Such, indeed, is the demand upon the endurance and physical strength of those concerned that, unless sustained by their conviction of the efficacy and unchallengeable superiority of the open operative procedure, they would be extremely unlikely to continue for long to practice it.

The Various Methods Employed.—In my earlier paper I showed, in tabular form, the different methods employed in respect of all the bones in the first five years' series which were dealt with by direct fixation. The table may be reproduced here.

TABLE V

Showing the bones involved and the different methods of fixation employed in the first five years' series

	Wiring	Pinning	Plating	Screwing	Pin and plate	Ring plates	Total
Lower jaw	7	—	—	—	—	—	7
Clavicle	1	—	3	—	—	—	4
Clavicle, outer end	—	1	—	—	—	—	1
Humerus, upper end	—	4	1	—	—	—	5
Humerus, shaft	—	—	6	—	—	—	6
Humerus, lower end (T)	—	—	—	—	2	—	2
Humerus, lower epiphysis	—	16	—	—	—	—	16
Olecranon	5	—	—	—	—	—	5
Ulna	—	3	—	—	—	—	3
Radius	—	—	2	—	—	—	2
Radius and ulna	—	—	2	—	—	—	2
Metacarpal	—	1	—	—	—	—	1
Phalanx, finger	1	1	—	—	—	—	2
Femur, upper end	—	2	—	—	—	—	2
Femur, shaft	—	—	12	2	—	1	15
Patella	4	—	—	—	—	—	4
Tibia	3	—	22	—	—	—	25
Metatarsal	—	1	—	—	—	—	1
Totals	21	29	48	2	2	1	103

The methods included fixation by wire, by different kinds of pins or nails, by screws, and by combinations of these; also, in one case by ring plates.

Reference to the table will show that the total number of cases in the series treated by direct fixation was 103. Of these, twenty-one were treated by wiring, twenty-nine by pinning or nailing, forty-eight by plating, two by screw fixation, two by a combination of plate and pin, and one by ring plates. The bones so treated included the mandible, the clavicle, the humerus, the olecranon, the ulna, radius, metacarpals, phalanges of the fingers, femur, patella, tibia and metatarsals. In a considerable number of cases also, as the table shows, epiphyseal fracture-separations were treated by this method.

including the upper and lower epiphyses of the humerus and the upper epiphysis of the femur.

The second five years' series and the corresponding details, with respect to bones involved and the operative methods employed, are shown in the next table. (Table VI)

TABLE VI

Showing the bones involved and the different methods of fixation employed in the second five years' series

	Wiring	Pinning	Plating	Screwing	Wiring and pinning	Wiring and plating	Wiring and screwing	Metal band	Catgut suture	Total
Mandible	1	—	—	—	—	—	—	—	—	1
Clavicle	1	—	1	—	1	—	—	—	—	3
Clavicle, outer end, or acromio-clavicular joint	—	2	—	—	—	—	—	—	—	2
Humerus, upper end	—	2	2	—	—	—	—	—	—	4
Humerus, shaft	—	—	4	—	—	—	—	—	—	4
Humerus, lower end (T)	—	1	1	—	—	1	—	—	—	3
Humerus, lower epiphysis (Capitellar)	—	6	—	—	—	—	—	—	—	6
Humerus, lower epiphysis (internal condyle)	—	6	—	—	—	—	—	—	—	6
Olecranon	6	4	—	—	—	—	—	—	1	11
Ulna	2	—	3	—	—	—	—	—	—	5
Radius	2	4	8	2	—	1	—	1	—	18
Metacarpal	—	2	—	—	—	—	—	—	—	2
Phalanx, finger	—	1	—	—	—	—	—	—	—	1
Pelvis, ilium	—	1	—	—	—	—	—	—	—	1
Femur, upper end (neck)	—	3	—	—	—	—	—	—	—	3
Femur, shaft	2	—	17	—	—	1	1	—	—	21
Patella	6	—	—	—	—	—	—	—	2	8
Tibia	1	—	24	—	—	—	—	—	—	25
Tibia malleolus	—	—	—	—	—	—	—	—	1	1
Fibula	1	—	—	—	—	—	—	—	—	1
Totals	22	32	60	2	1	3	1	1	4	126

It will be seen, by reference to this table, that the bones dealt with are very much the same as those in the earlier period, and that the numbers of each are not greatly different from the earlier period. It will also be observed, however, that whereas in Table V the columns into which the various methods have been divided are only six in number, in Table VI, the columns have increased to nine in virtue of additional combinations in the mechanical technic of fixation.

The total number of cases dealt with by open operation and direct fixation in the second five years' period amounted to 126 (compare with 103 in the previous period). Of these, twenty-two were treated by wiring, thirty-two were pinned or nailed, sixty were treated by plating, two were fixed by screw, in one case wiring and pinning were employed together, in three cases wiring and plating were combined, in one case wiring and screwing were employed

together, in one case a metal band was used, and in four cases the fixation method involved the use of catgut suture instead of any metallic medium.

In this series, as in the previous one, is included a considerable number of cases of epiphyseal fracture-separations, particularly at the lower end of the humerus, in the treatment of which, where there is anything beyond the most trifling displacement, direct fixation is, in our considered opinion, almost always the only correct line of procedure.

The figures for the two periods of five years have been combined in the following table (Table VII), reference to which will show the details for the consecutive ten years' period.

TABLE VII

Showing the bones involved and the different methods of fixation employed in the combined ten years' series

	Wiring	Pinning	Plating	Screwing	Wiring and pinning	Wiring and plating	Wiring and screwing	Pin and plate	Metal band	King plate	Catgut suture	Total
Mandible	8	—	—	—	—	—	—	—	—	—	—	8
Clavicle	2	—	4	—	1	—	—	—	—	—	—	7
Clavicle, outer end, or acromio-clavicular joint	—	3	—	—	—	—	—	—	—	—	—	3
Humerus, upper end	—	6	3	—	—	—	—	—	—	—	—	9
Humerus, shaft	—	—	10	—	—	—	—	—	—	—	—	10
Humerus, lower end (T)	—	1	1	—	—	1	—	2	—	—	—	5
Humerus, lower epiphysis	—	28	—	—	—	—	—	—	—	—	—	28
Olecranon	11	4	—	—	—	—	—	—	—	—	1	16
Ulna	2	3	3	—	—	—	—	—	—	—	—	8
Radius	4	4	10	2	—	1	—	—	1	—	—	20
Radius and ulna	—	—	2	—	—	—	—	—	—	—	—	2
Metacarpal	—	3	—	—	—	—	—	—	—	—	—	3
Phalanx, finger	1	2	—	—	—	—	—	—	—	—	—	3
Pelvis, ilium	—	1	—	—	—	—	—	—	—	—	—	1
Femur, upper end (neck)	—	5	—	—	—	—	—	—	—	—	—	5
Femur, shaft	2	—	29	2	—	1	1	—	—	1	—	36
Patella	10	—	—	—	—	—	—	—	—	—	2	12
Tibia, shaft	4	—	46	—	—	—	—	—	—	—	—	50
Tibia, malleolus	—	—	—	—	—	—	—	—	—	—	1	1
Fibula	1	—	—	—	—	—	—	—	—	—	—	1
Metatarsal	—	1	—	—	—	—	—	—	—	—	—	1
Totals	43	61	108	4	1	3	1	2	1	1	4	229

As this table shows, the total number of cases treated by open operation and direct fixation in the ten years from May, 1917, to May, 1927 amounted to 229. Of this number, forty-three were wired, sixty-one were pinned or nailed, in 108 cases plating was employed, and the remaining seventeen were dealt with by various combinations of metallic fixation, or by catgut suture. The applicability of particular methods to particular bones will be referred to later.

Further Statistical Details Respecting the Second Five Years' Period.—It will be remembered that the total number of cases of fracture in the second

five years' series was 632. This number, of course, has reference to patients: it does not represent the number of bones fractured. An analysis of the records, indeed, brings out the fact that in these 632 patients, 912 different bones were affected, and in respect of the ribs, metacarpals, metatarsals and phalanges, even this number would require to be considerably augmented.

I have shown in a further table (Table VIII) an analysis of the series, taking 912 as the number of bones involved instead of the 632 patients affected.

TABLE VIII

Showing the total numbers of bones involved in the second five years' period—with relative particulars

	Total fractures	Treated without open operation	Treated by open operation without direct fixation	Treated by direct fixation	Percentages for each bone treated by direct fixation
Skull, vault	34	9	25	—	—
Skull, base	68	44	24	—	—
Nasal bones	15	4	11	—	—
Maxilla	1	—	1	—	—
Malar	5	2	3	—	—
Mandible	9	2	6	1	11.1
Ribs (multiple)	54	46	8	—	—
Sternum	2	2	—	—	—
Clavicle	28	23	2	3	10.7
Acromio-clavicular joint (Fracture dislocation)	2	—	—	2	100
Scapula	7	7	—	—	—
Humerus	75	46	6	23	30.6
Olecranon	14	2	1	11	71.4
Radius	94	59	17	18	19.1
Ulna	61	41	15	5	8.2
Metacarpals (multiple)	13	2	9	2	15.1
Scaphoid	4	2	2	—	—
Semilunar	2	—	2	—	—
Phalanges, fingers (multiple)	42	1	40	1	2.4
Spine	11	8	3	—	—
Pelvis	26	16	9	1	3.8
Coccyx	1	—	1	—	—
Femur	71	39	8	24	33.8
Patella	12	3	1	8	66.6
Tibia	111	68	17	26	23.4
Fibula	108	96	11	1	.9
Tarsus, various	4	2	2	—	—
Astragalus	3	3	—	—	—
Os calcis	13	12	1	—	—
Metatarsals (multiple)	18	11	7	—	—
Phalanges, toes (multiple)	4	2	2	—	—
Totals	912	552	234	126	—

In this table the first column shows the numbers for the particular bones. The second column gives the numbers in which no open operation was employed. In the third column are shown the numbers for the particular bones in which some form of open operation was carried out, but in which no mechanical, direct fixation was employed. The fourth column gives the numbers of those treated by direct fixation, and in the last column are the

percentages in the case of each bone where some form of direct fixation was employed.

It will be observed, by reference to the last column of Table VIII, that, in the case of the bones treated by direct fixation, the percentage frequency of application varies within wide limits. The percentages for each bone, as shown in this column, have been arranged in a further table (Table IX), showing the respective frequency in ascending progression. The result of this analysis works out very much as one would have expected, especially as indicating that the bones most frequently dealt with by direct fixation, apart from certain fractures at the outer end of the clavicle and fracture-dislocations of the acromio-clavicular joint, are the olecranon 71.4 per cent., the patella 66.6 per cent., the femur 33.8 per cent., the humerus 30.6 per cent., the tibia 23.4 per cent., and the radius 19.1 per cent. The percentages in these are based on considerable numbers. The lower percentages in the remaining bones, except in the case of the phalanges, are based on much smaller numbers.

TABLE IX

Showing percentage frequency of employment of direct fixation by open operation in respective bones, in the second five years' period—arranged in ascending progression

Fibula	.9
Phalanges, fingers	2.4
Pelvis	3.8
Ulna	8.2
Clavicle	10.7
Mandible	11.1
Metacarpals	15.1
Radius	19.1
Tibia	23.4
Humerus	30.6
Femur	33.8
Patella	66.6
Olecranon	71.4
Acromio-clavicular joint (Fracture-dislocation)	100.0

The Choice of Method.—Reference to the various tables indicates that, in the great majority of fractures of the long bones, one or other of three different methods has been employed, namely, *wiring*, *pinning*, or *plating*. The cases dealt with by these three methods have far out-numbered all the others put together.

The actual choice of method must always depend on the judgment of the particular operator in the particular case. He will be influenced in his decision by various factors. His purpose is, or should be, to secure the most adequate restoration of function with the minimum of risk, and the maximum of accuracy in the adjustment of the fragments. He will be swayed by anatomical considerations. He will in some cases be prevented from adopting a particular method, which otherwise he might desire to employ, by conditions imposed on him by such anatomical considerations. He must not risk undue

interference with the local circulation, or with important nerve supply, in the course of the adequate exposure of the bone fragments which he desires to readjust and to fix in proper alignment. He may require therefore, in some cases, to choose a method which does not adequately meet his wishes, and to rest content it may be, with something a good deal short of the ideal. The

A B

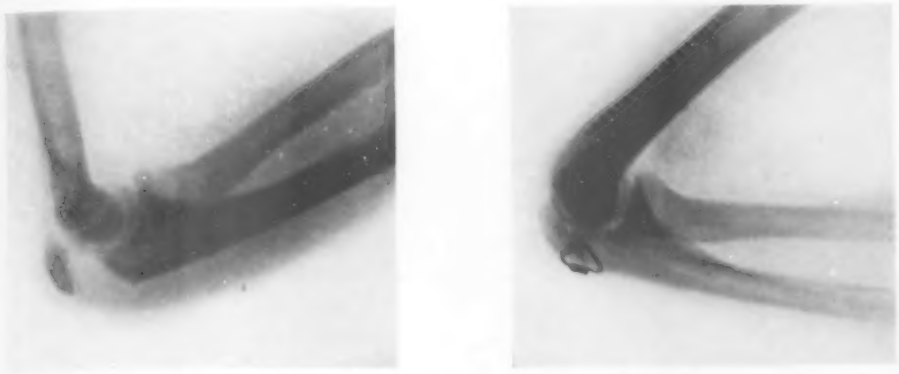


FIG. 1.—Fracture-separation of olecranon epiphysis—wired.

"second" best, indeed may in certain circumstances be the method of election. He must nevertheless endeavor, where possible, to obtain as perfect alignment and restoration of the anatomical normal as are within his power; for, other things being equal, correct alignment is one of the most important pre-requisites for perfect functional restoration.

A B

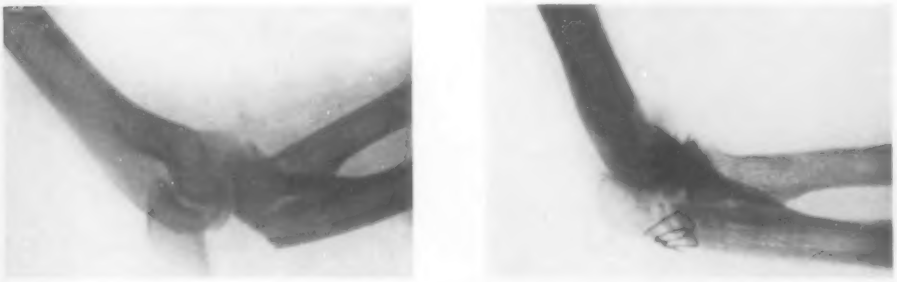


FIG. 2.—Fracture of olecranon—wired.

Wiring.—It will be seen that in each of the five years' periods the number of cases dealt with by wiring alone represents roughly a *fifth* of the whole. The bones to which this method of treatment has chiefly been applied have been the mandible, the olecranon [Figs. 1 (A and B); 2 (A and B); and 3], the patella [Figs. 4 (A and B)], and the clavicle [Figs. 5 (A and B)]. It seems likely that these bones will continue to be the ones in which this method of treatment will most frequently be employed.

The chief difficulty with which the surgeon has had to contend in the wiring of fractures has generally been due to the unsatisfactory quality of

the wire used. It may be said that this should be as fine as possible, consistent with the necessary tensile strength for the particular case in which

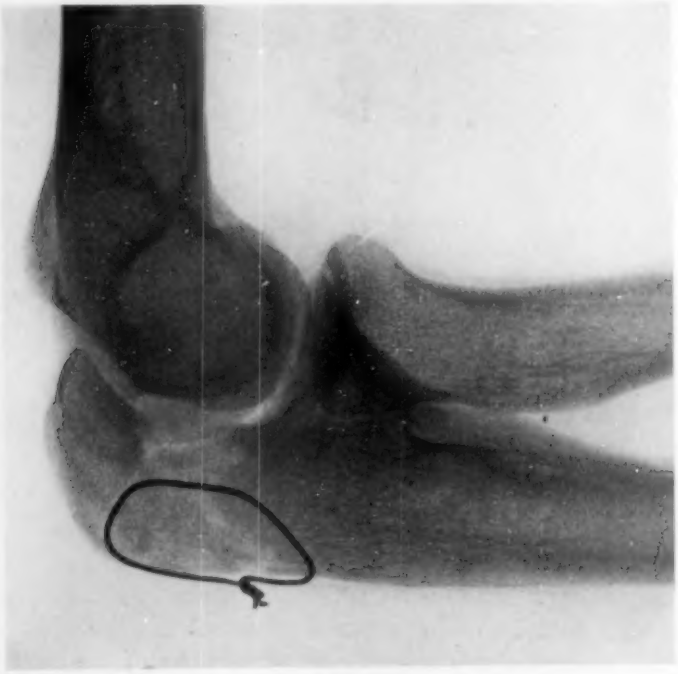


FIG. 3.—Fracture of olecranon—wired.

it is employed. In the earlier years, when wiring of bones began to be practiced, silver wire was chiefly used, but this was generally found to be

A B

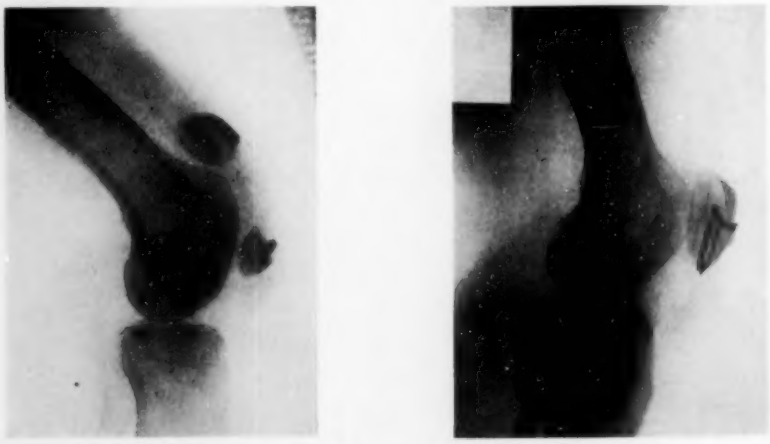


FIG. 4.—Fracture of patella with wide separation—wired.

unsatisfactory unless a very thick wire was employed. The finer grades of silver wire were very apt to break at the twist point when anything like the

requisite firmness of application was attempted, and it must have been the experience of most surgeons to have such an accident occur frequently at the most critical stage in the procedure.

Many other types of wire have, in consequence, been tried in the endeavor to obtain a material which will normally withstand the strains for which silver wire has so often proved itself unsuitable. In my previous paper I indicated that I had been using, for a considerable time, a brass wire which seemed to meet the requirements of its effective use much more adequately than silver wire, and I exhibited, to the surgical section of the British Medical Association, samples of this brass wire in different grades, most of them of comparative thinness. I have continued using brass wire, and on the whole have found it greatly more satisfactory than silver wire. On the same occasion I mentioned, and showed to the section, samples of other types of wire: nickel, and monel metal (an alloy of copper and nickel in the

A B

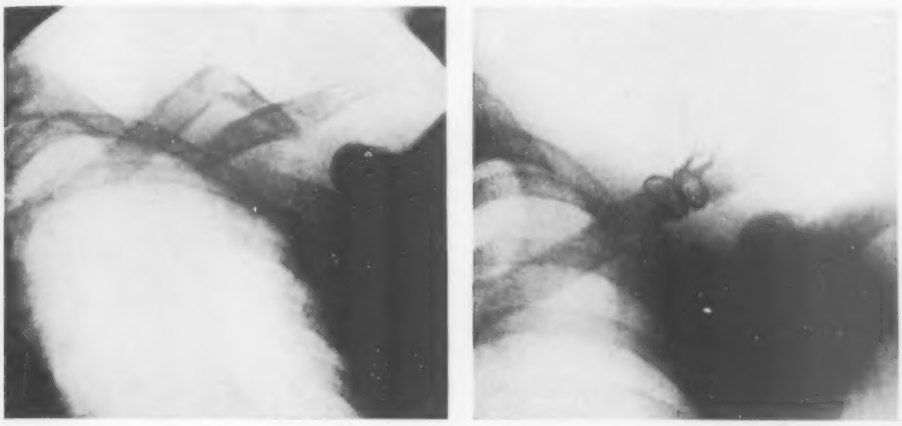


Fig. 5.—Fracture of clavicle, with separation and downward tilting of a central fragment. Replacement by open operation, and fixation by wiring.

proportion of 67 per cent. copper and 33 per cent. nickel). Neither of these wires has proved itself so satisfactory as the simple brass wire, and I have not found that the brass wire exerts upon the tissues any obvious harmful effect. Nor have I found that it is acted upon by the tissues to any appreciable extent.

This brass wire—and even the finest grades of it—is strong, pliable, and easy of employment. If used with care it can be twisted to the point of absolute stabilization with the minimum of risk of snapping. It is suitable both for the direct fixation of bone fragments, and in the case of fractures of the mandible, for the wiring of teeth. This is particularly important where the teeth are so closely set that the difficulty of wiring them together would be greatly enhanced if one were under the necessity of using a thick wire such as silver. The fine-grade brass wire can be slipped very easily between even fairly closely set teeth, and can be wound several times round and between the adjacent teeth which one desires to utilize as fixation points.

In my previous paper I referred to a case of fracture of the mandible, and showed a radiogram from the case, in which the bone fragments were directly fixed by means of a single fine wire; the fixation was absolute, and the alignment as nearly perfect as possible. One can hardly imagine the possibility of achieving such a result with a single silver wire, twisted to the degree necessary to produce absolute stabilization, without the wire snapping. (Fig. 6)

The fixation of the fragments of a fractured mandible by wiring of the adjacent teeth is illustrated in Fig. 7.

In addition to the employment of wiring by itself, we have made use of it, during the second five years' period, also in combination with other methods. Reference to Table VI will show that we have employed it along with pinning, with plating, and with fixation by screws. It is likely that we shall

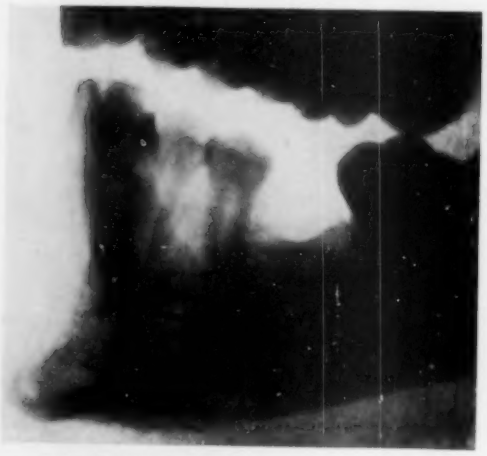


FIG. 6.—Fracture of mandible, showing how fixation was effectively secured by a single fine brass wire. No external splint was employed.

FIG. 7.—Fracture of the mandible. Fixation by wiring of teeth.

continue to employ it, from time to time in selected cases, along with other methods.

It is obvious that in certain fractures of the long bones, such as femur, or humerus, or in fractures in which one or more small but essential fragments have been partially detached from the main fragments, the use of one or more wires penetrating or encircling the main and subsidiary fragments is a reasonable procedure. One could give several illustrative examples from our experience—examples both of simple wiring and of the uses of wiring in supplement to other methods of fixation.

Pinning or Nailing.—As in the first five years' period, so also in the second, the number of cases treated by this method has been considerable, amounting to roughly *a quarter* of all the cases operated on by direct fixation. In my former paper, I described the different kinds of nails or pins which we had been accustomed to employ. (Fig. 8) In the earlier years, we used relatively thick and heavy nickel or silver-plated steel pins of vary-

ing length, and very much of the same type as we had been in the habit of employing for fixation purposes after resection of the knee.

For certain purposes we still employ, and must continue to employ, nails of this character—relatively thick, strong, and sometimes of considerable length; even as much as four or five inches.

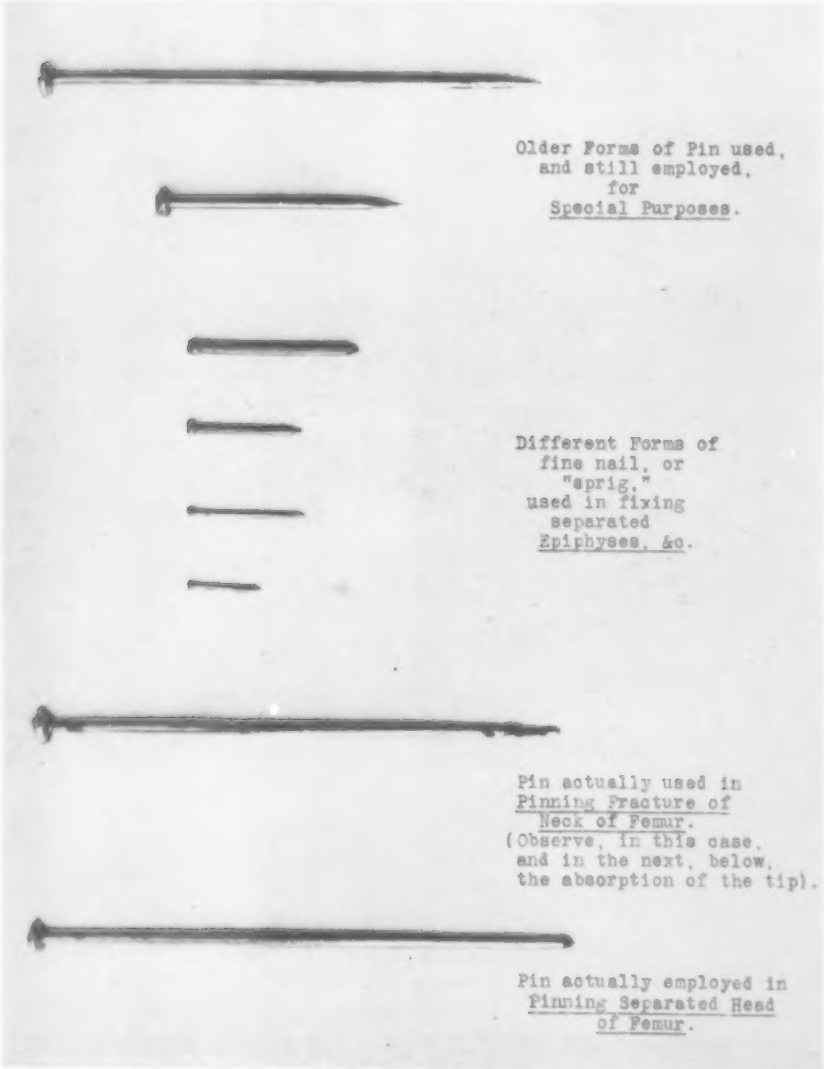

Older Forms of Pin used, and still employed, for Special Purposes.
Different Forms of fine nail, or "sprig," used in fixing separated Epiphyses, &c.
Pin actually used in Pinning Fracture of Neck of Femur. (Observe, in this case, and in the next, below, the absorption of the tip).
Pin actually employed in Pinning Separated Head of Femur.

FIG. 8.—Showing different kinds of the larger steel pins and the finer "sprigs" employed. At the lower part of the figure are shown two long steel pins, actually used in fixing fractures of the neck of the femur. Note the absorption of their tips.

Nails of this character we continue to use in certain fractures of the upper femoral epiphysis or fractures of the neck of the femur, particularly intracapsular fractures with minimal fragmentation or comminution. In suitable cases the use of a single long pin of this character furnishes a simple

and effective means of fixing the detached articular head to the separated neck or upper end of diaphysis. It is seldom desirable to attempt to do this without making a free opening into the hip joint from the front, the fragments being adjusted as accurately as possible, and set into proper relation with each other, before the long pin is introduced. We have generally exposed the joint through an anterior incision, very much like the one used in

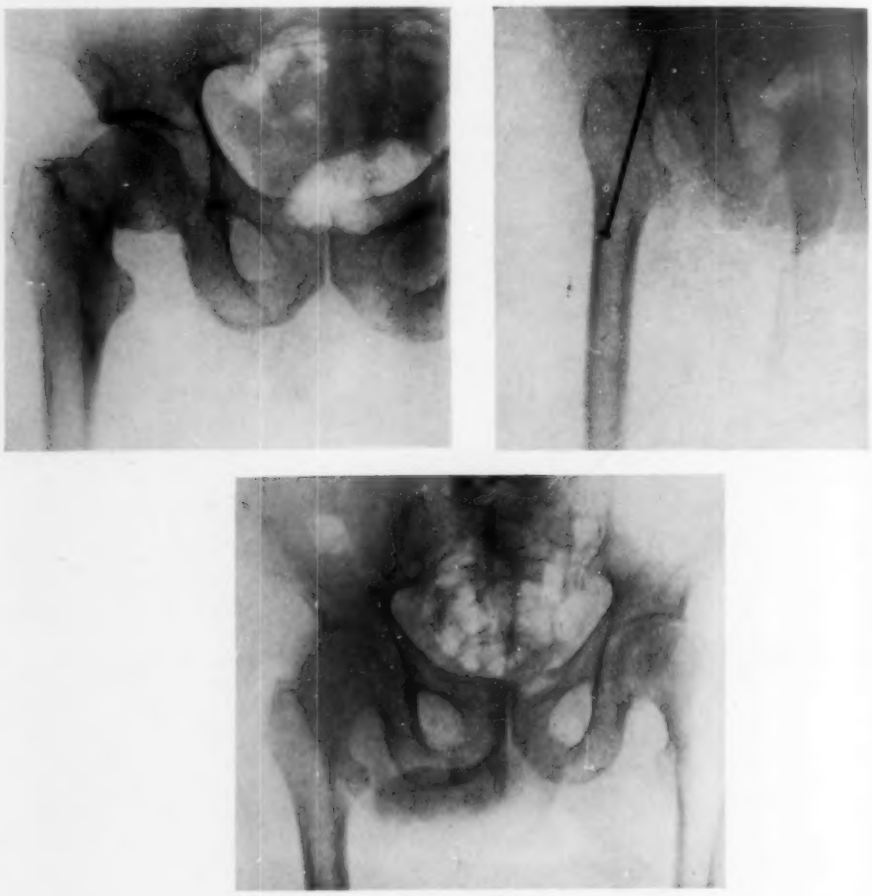


FIG. 9.—Fracure of the neck of the femur. Fixation by a long steel pin passed from the diaphysis upwards along the neck into the femoral head; (A) Showing fracture and displacement; (B) Showing nail in position, after replacement; (C) Three months after—union complete.

Barker's method of excision of the hip. This gives free and adequate exposure of the joint and of the fractured neck, and once the right degree of adjustment has been secured, the nail is introduced through a separate puncture of the skin on the outer surface of the limb, at a point an inch or two below the tip of the great trochanter. From there, it is driven as nearly as possible axially along the femoral neck, until it penetrates the main articular

fragment. Into this it is driven firmly by light taps of a hammer. The head of the pin or nail is left projecting through the skin puncture until the nail has served its purpose—say, after six or eight weeks—when it is easily removed. We have employed this method in fractures at the upper end of the femur in three cases in the second series, and more recently still in several other cases of the same kind. I know of no other method which has proved itself, in our hands, so satisfactory as this is in the treatment of such injuries. [Figs. 9 (A, B, and C.)]

In similar fractures, or epiphyseal separations, at the upper end of the humerus, we have quite often fixed epiphysis and diaphysis, or proximal and distal fragment, effectively together by the use of a single long pin or nail, introducing it in some cases from below upwards, and in others from

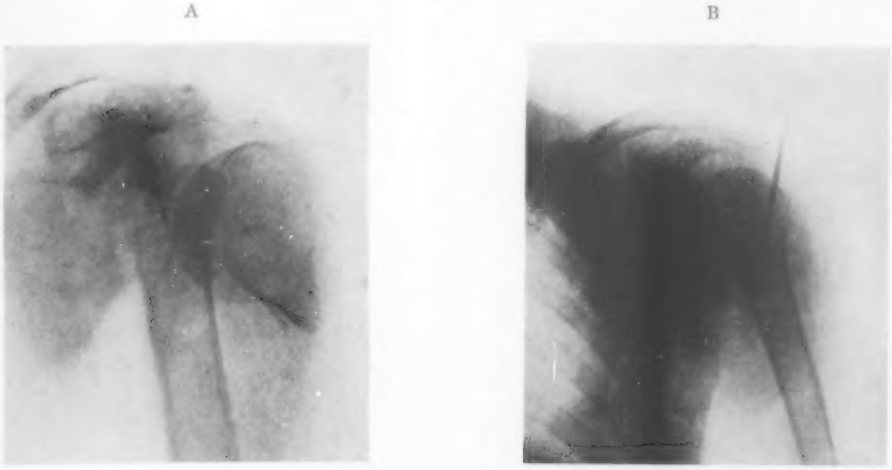


FIG. 10.—Fracture of upper end of humerus in an adult woman: (A) Showing gross displacement of distal fragment into axilla; (B) Replacement and fixation by a long pin passed from the proximal fragment into the distal. (Dr. A. J. Hutton.)

above downwards, i.e., from diaphysis below driven obliquely upwards and inwards into the articular head, or from the epiphysis or upper end of the humerus downwards and inwards into the diaphysis. Both methods we can readily illustrate from our records of this and of the previous five years' period. [Figs. 10 (A and B); 11 (A and B)]

Occasionally a second nail of equal length may be required in order to accomplish the necessary degree of effective fixation, and in one case we actually employed three of these long pins before we were satisfied that we had obtained sufficiently stable fixation.

In my earlier paper I alluded to a special little group of injuries in the region of the outer end of the clavicle and the acromio-clavicular joint, where very satisfactory fixation and alignment of fragments could be obtained by means of the introduction of a single long steel nail, and I illustrated one of these. I refer, in particular, to those fractures of the extreme outer end of the clavicle, where replacement and fixation of the small distal or acromial

fragment are difficult, and in some cases practically impossible of accomplishment by ordinary means. The method of application is simple.

The fracture area is exposed through a suitable, but small incision. The fragments are adjusted, and are maintained by simple means in their normal

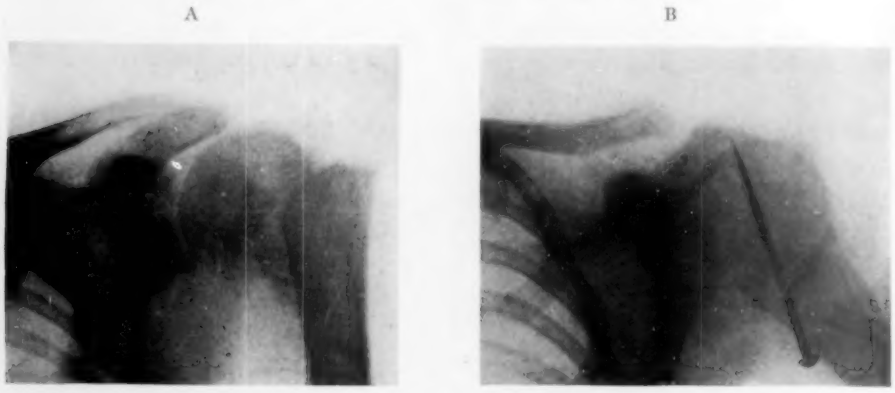


FIG. 11.—Fracture of upper end of humerus. (A) Showing gross outward and upward displacement of distal fragment; (B) Replacement and fixation by a long pin passed upwards from distal fragment into the proximal.

relation to each other, while a long steel pin of this strong type is passed through a small puncture made in the skin, external to the acromion, axially right through the outer fragment and on into the shaft of the clavicle. If necessary it may perforate the acromion and traverse the acromio-clavicular

FIG. 12.—Fracture of the outer end of the clavicle in an adult male: (A) Showing gross displacement; (B) Correction by open operation, and fixation by a long steel pin.

joint before perforating either of the clavicular fragments. [Figs. 12 (A and B)]

This same method we have employed, on a number of occasions, to prevent or control the troublesome upward displacement of the acromial end of the clavicle in the not uncommon dislocation at the acromio-clavicular joint. As I said before, I know of no equally effective method of controlling the upward rising acromial end of the clavicle. Fixation by plate and screws, or by simple pinning, or by wiring, is of little use. The introduction of the

simple long steel pin in the manner that I have described has proved itself in our hands to be easy, effective and satisfactory. Nor does it, as might be supposed, interfere to any appreciable degree with the function and useful movement one desires to preserve at this joint. [Figs. 13 (A and B)]

A B

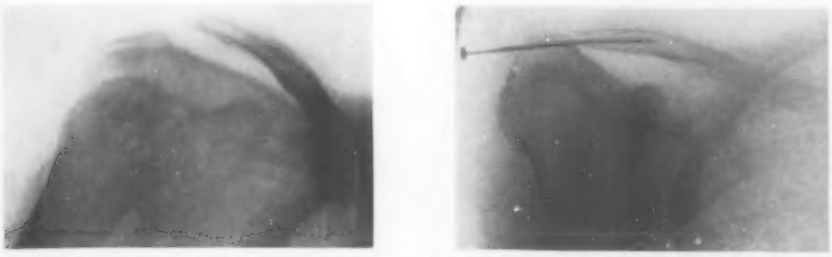


FIG. 13.—Dislocation at acromio-clavicular joint: (A) Showing gross upward displacement of acromial end of the clavicle; (B) Correction by open operation, and fixation by a long steel pin.

Both in the case of fractures of the outer end of the clavicle, and in dislocation of the acromio-clavicular joint, the pin has served its purpose and may be withdrawn with safety at the end of three or four weeks.

Another type of injury in which we have found the use of such a long steel pin to be very effective is the troublesome T-shaped fracture at the lower end of the humerus. We have found great difficulty sometimes in

A B C

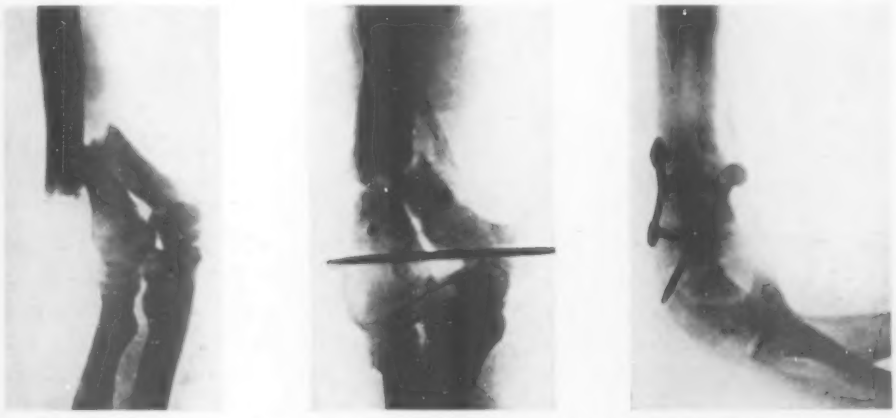


FIG. 14.—Fracture of lower end of humerus in a young adult male—T-shaped, into elbow joint: (A) Showing the gross displacement of fragments; (B) After pinning and plating (anterior-posterior view); (C) The same in profile.

maintaining the two lower fragments in proper apposition during the introduction of the plate or plates required to secure them to the diaphyseal fragment. They tend to rotate on their long axes, no doubt as the result of the attachment to each of one or other of the two main groups of forearm muscles, namely, the flexor-pronator and extensor muscles respectively. This difficulty is got over by first of all passing a long steel pin from side to side, right through both fragments. This effectively steadies them, and

the plates and screws can then be applied with less difficulty. This was well illustrated in my earlier paper, and the illustrations may be reproduced here. [Figs. 14 (A, B and C)]

With these exceptions, however, it may be said that we have come to employ, in most cases, much finer nails or pins. For most purposes the larger and thicker pins or nails are quite unsuitable: they are very apt to

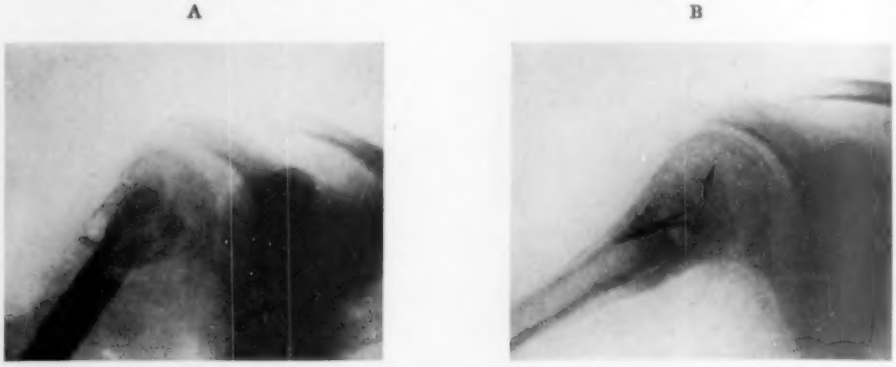


FIG. 15.—Fracture of upper end of humerus: (A) Showing impaction of distal fragment into the proximal; (B) After correction, and fixation by three fine "sprigs."

cause splitting of the fragments into which they are driven unless these fragments are previously drilled for their reception. In many cases they are obviously much too bulky; they require, for their introduction, the expenditure of much greater force than seems to be justifiable; and there is a good deal of scattering of bone dust into the surrounding tissues during the process of drilling. Nor do they give any more effective fixation than do the finer agents which we now very largely employ. [Fig. 15 (A and B)]

FIG. 16.—Fracture of upper end of ulna. Fixation by a single fine "sprig."

This is particularly the case in those fractures or fracture-separations of the lower epiphyses of the humerus which we now treat so generally by open operation and direct fixation. In the case of these injuries very little is required to fix the fragments, and the finest steel pins or "sprigs" are as effective as could be desired. We use these of varying length, from three-quarters of an inch in length up to, at the most, an inch and a half. They are the ordinary "sprigs" or "fine wire nails" used by the carpenter, and as a matter of fact, we obtain them from the infirmary carpenter from time to time as we require them. Their cost is practically "nil"; we use them unplated; and in many cases, they are left permanently buried in the bone where they do no harm.

We have used them in many other situations as well; in fractures of the

olecranon, of the forearm bones, of the upper end of the humerus, in fixation of malleolar fractures, and also in a certain number of fractures of the

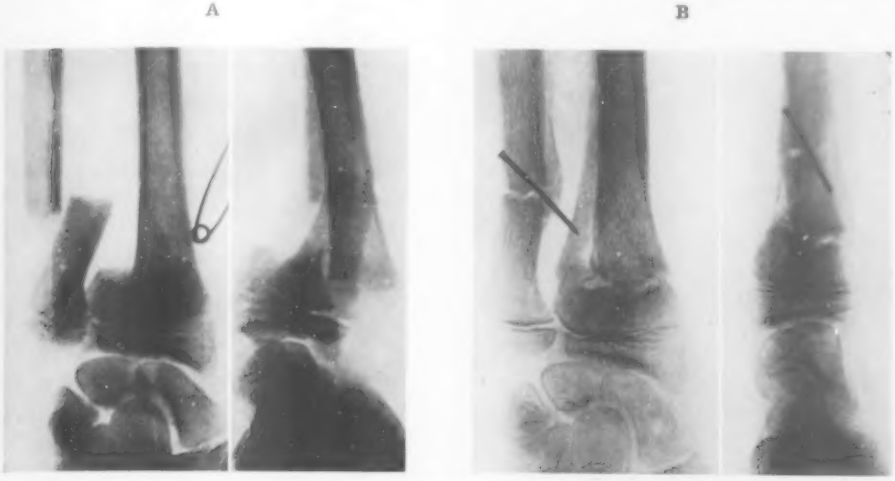


FIG. 17.—Fracture of both bones of forearm near the lower end: (A) Showing gross displacement of the fragments (anterior, posterior and profile views); (B) Result after correction by open operation, and fixation of the ulnar fragments by a single fine "sprig" (anterior, posterior and profile views).

phalanges of the fingers, and in fractures of the metacarpals and metatarsals, the pin being introduced axially from one fragment into and along the other, and being left as a permanent central axis in the realigned bone. It does no harm in its new bed. [Figs. 16, 17 (A and B), and 18]

This axial implantation of a fine nail or "sprig" I have employed also in certain cases of fracture of the clavicle, alone, or in combination with circular wiring.

FIG. 18.—Fracture-separation, distal epiphysis of the radius, with gross displacement. Correction and fixation by a single fine "sprig."

As I pointed out in my former paper these finer pins or nails, which are sometimes of the rounded type, and sometimes flattened in section, head as well as nail length, have the advantage that they do not readily split the fragile fragments into which they are introduced; that they do the minimum of damage to epiphyseal cartilage and growth centres; and that they are generally so easily driven home. In the comparatively soft bone of a young person such fine pins can often be driven well home without any preliminary drilling, and without the application of much force. As a rule, a few light taps with the heavy end of a periosteal elevator or with a light hammer may be required, but that is all.

In the second five years' series the bones which have been treated by simple pinning have been clavicle, humerus, olecranon, radius, metacarpal, phalanx of the finger, pelvis and the upper end of femur.

Plating.—As in the first series, so also in the second, the number of cases dealt with by plating has been much larger than the number of these treated by any of the other methods. They have amounted, in fact, to almost *half* of the total. Femur and tibia have been plated most frequently of all. The tibia was plated twenty-four times, the shaft of the femur seventeen times, the radius eight times, the shaft of the humerus four times, the ulna three times, the upper end of the humerus twice, the lower end once, and the clavicle once.

This method has been so long in use, and in proper hands has given so

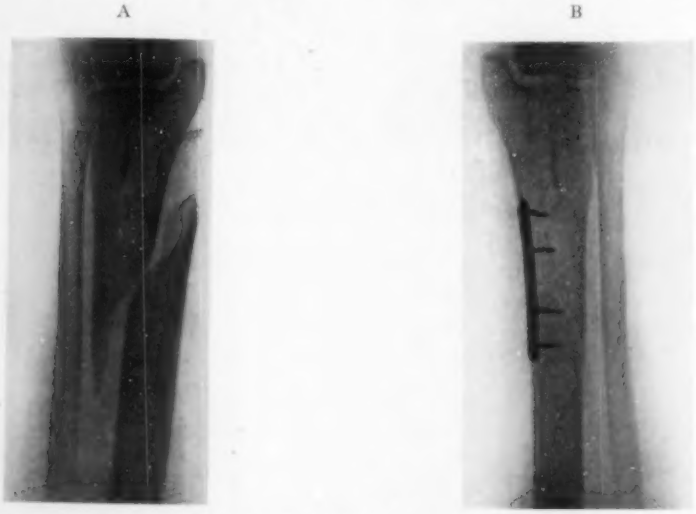


FIG. 19.—Spiral fracture of the lower third of tibia. Fixation by plate and screws. (The fibula, broken in the upper third, required no special treatment.) (A) Showing the long, oblique, spiral fracture of the tibia, with longitudinal splitting of the distal fragment; (B) Showing the "hair-line" adjustment of the plated fragments.

satisfactory results that little further need be said here regarding it. I offered the opinion, in 1922, that it was probable that the expedient of plating would tend to become confined more and more to the treatment of fractures of the tibia, the femur and humerus. The experience of the second five years would seem to bear out this prophecy, except that the bones of the forearm may require to be added. I took the view, and I see no reason to alter it now, that, in the case of most of the other bones, wiring or pinning would probably become the operation of choice. [Figs. 19 (A and B); 20 (A and B); 21 (A and B)]

Our practice in respect of the later removal, or not, of the plate and screws is not according to any fixed or hard-and-fast rule. We seldom remove a plate which has been used in fixing a fracture of the femur. Deeply buried as it is beneath the bulky muscles of the thigh, it seldom gives rise to any trouble, and we do not, as a rule, contemplate requiring to remove it.

A

B

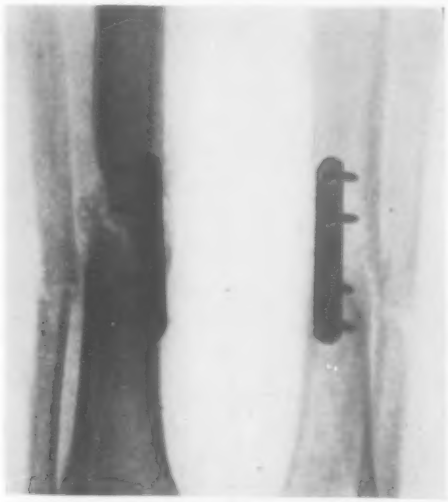
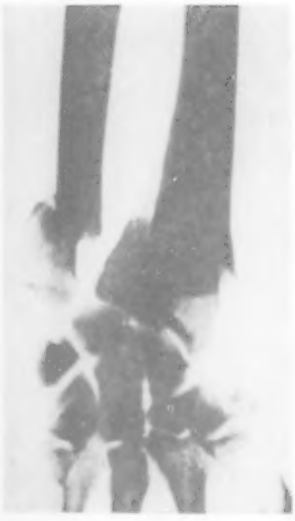


FIG. 20.—Severe compound, comminuted fracture of tibia and fibula. Caused by direct violence. Treated for some months in another hospital. Gross displacement of fragments, and greatly delayed union.

Open operation, and fixation of the main tibia fragments by plate and screws. The fibular fracture was exposed through a separate wound, and portions of both fibular fragments had to be removed to permit of the tibial fragments being adjusted. A V-shaped gap on the fibular aspect of the tibia was filled in by bone chips. The resul was excellent. (A) Showing the gross displacement of fragments; (B) The satisfactory adjustment, and fixation of the tibial fragments.

A



B

FIG. 21.—Mal-united fracture of the distal ends of radius and ulna. Injury nine weeks before the patient came under observation. Caused by direct violence.

Open operation, and fixation by plating of both bones through separate incisions. (An excellent functional and æsthetic result.) (A) Showing gross displacement of fragments; (B) Showing the readjustment, and fixation by plates.

On the other hand, in the case of the tibia, which for so considerable a part of its length is practically subcutaneous, we quite often remove the plate and screws as a procedure of choice once the immediate purpose of its introduction—namely, the accurate maintenance of correct alignment while repair processes are going on—has been secured. In the case of an artisan, whose return to work at the earliest possible period is desired, and who is in the course of his work, exposed to many chances of minor injury to the leg, we frequently remove the plate and screws within a couple of months of their introduction. In the case of other bones the retention or removal of the plate is determined according to factors which vary for the particular individual, and with social and other circumstances.

Screwing.—In the first five years' series were included two cases in

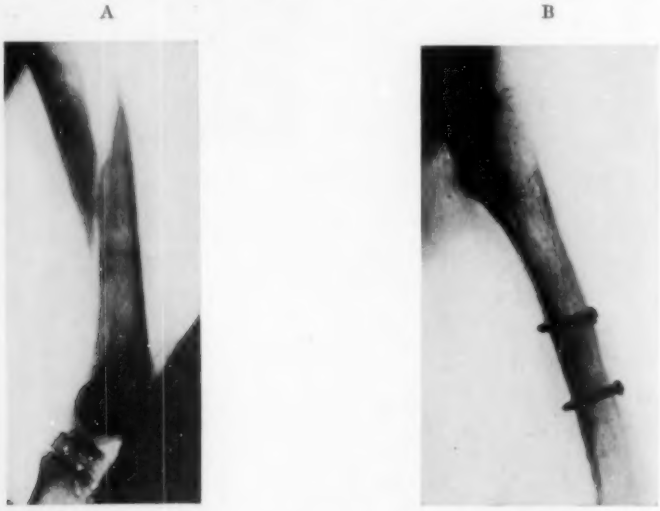


FIG. 22.—Long oblique fracture of the shaft of the femur in a young girl: (A) Showing the gross displacement; (B) Correction by open operation, and fixation by two screws.

which long, oblique, spiral fractures of the shaft of the femur were secured by screws alone. In one case a single screw was employed, and it was quite effective. In the other case, two screws were introduced a very short distance apart. Both cases did well. An illustration from one of the cases is worthy of reproduction here; it shows well the perfect readjustment and re-alignment of the fragments in a very nasty, oblique, spiral fracture of the femur of a young girl. [Figs. 22 (A and B)]

In the second series only two cases were treated by screwing (in both the bone was the radius). I may say here that, in the three years since the expiration of that second five years' period, we have employed the method on several other occasions for fractures of the femur, and with satisfaction.

Combined and Other Methods.—In the section dealing with pinning, reference has already been made to the combination of wiring with pinning in the treatment of certain fractures of the clavicle. In this series, wiring has been combined with plating. [Figs. 23 (A and B)]

This combination was employed also in T-shaped fracture of the lower end of the humerus, in fracture of the radius, and in a very badly com-

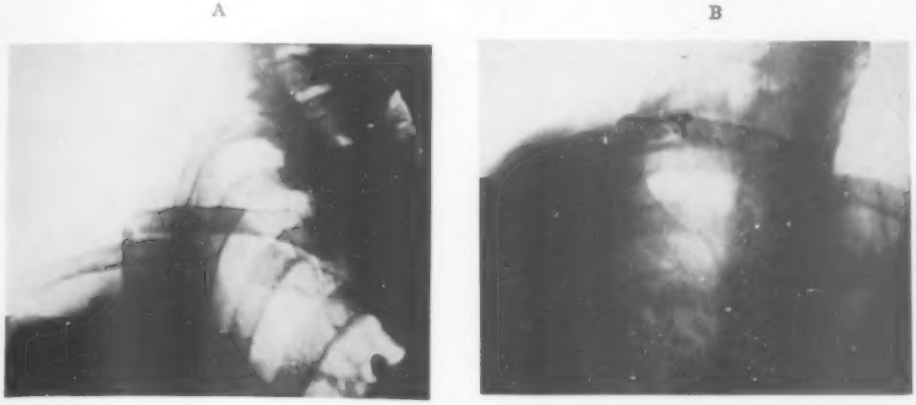


FIG. 23.—Comminuted fracture of the clavicle, with separation and tilting downwards of detached central fragment.

Open operation. Fragments freed. Two main fragments united by fine bridge-plate; gap made up by replacement of the central fragment, which was projected downwards in dangerous proximity to the vessels, etc. This was fixed in position by three fine brass encircling wires. The result was excellent. (A) Showing the gross displacement, and the downward tilting of the central fragment; (B) After treatment by open operation, and fixation by plate and encircling wires.

minuted fracture at the upper end of the shaft of the femur. An X-ray illustration of this last case shows very well the effective readjustment of a very complicated comminuted fracture which we were able to obtain by

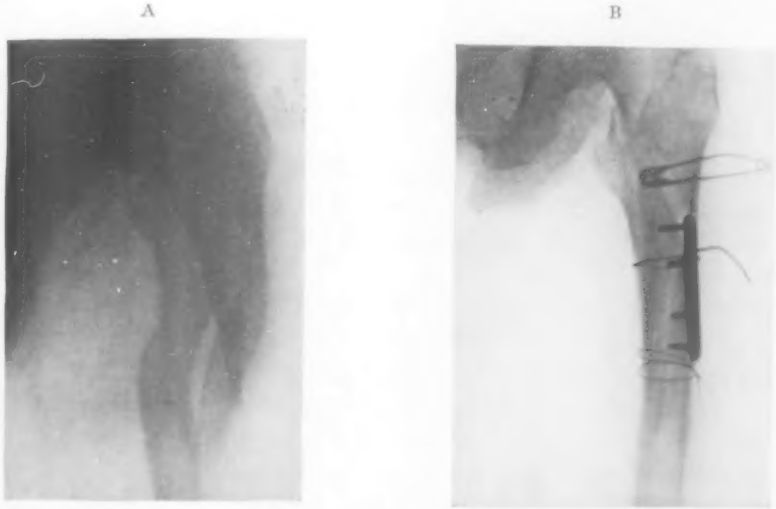


FIG. 24.—Fracture of the upper end of the shaft of the femur, with extensive comminution, longitudinal splitting of he bone, and wide separation of the fragments, one of which included the lesser trochanter.

Open operation. Replacement of the fragments in good alignment, and fixation by plate and screws, and three encircling wires. (A) Showing wide displacement of fragments; (B) After replacement, and fixation.

this means. [Figs. 24 (A and B)] In one case, a fracture of the shaft of the femur, wiring was used in combination with screwing.

In a single case operated upon in my wards by a colleague, a fractured

ulna was effectively secured by the application of a metal band around the site of fracture. (Fig. 25)

In four cases in the second five years' series, fixation was secured without the use of any metallic medium. The agent employed was catgut. As might be expected, two of these cases were fractures of the patella, one was a fracture of the olecranon, and one a fracture of the tibial malleolus. In the case of patella and olecranon the catgut sutures were passed through the bone fragments just as one might have passed metallic wire, but they were supplemented by additional catgut sutures passed superficially and laterally, in such a manner as to secure the closely related and damaged aponeurotic covering and the lateral aponeurotic expansions of quadriceps or triceps. In the case of the malleolar fracture the catgut sutures were entirely superficial.

Special Applicability of Direct Fixation to Particular Bones.—From consideration of the foregoing, and from the relative tables, it is obvious that direct fixation by open operation as anything like a routine procedure, is specially applicable to a somewhat limited group of bones. These are the olecranon, the patella, the femur, the humerus, the tibia, the radius (and, to a lesser extent, the shaft of the ulna). Less frequently, fractures of the clavicle, the mandible, and the shorter long bones, such as the metacarpals and phalanges, call for operative interference and for the adoption of some simple method of internal fixation.

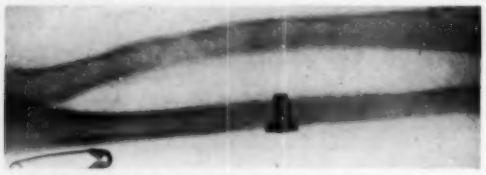


FIG. 25.—Fracture of both bones of the forearm—the radius in the upper third, with practically no displacement, and the ulna at the middle of the shaft. Replacement of the ulnar fragments, and fixation by a single metal band. (Radiograph—nine years after.)

The particular method, or combinations of methods, to be adopted in any given case will vary widely with factors of different kinds. Some of these have been already referred to, and the subject therefore calls for no further elaboration here.

Indications for Adoption of Open Operation and Direct Fixation.—In my earliest communication on this subject, before the section of surgery of the British Medical Association twenty years ago, I suggested a number of principles which should guide one in deciding upon open operation in any given case of fracture. These were as follows:

First of all, and of chief importance, the obliquity of a fracture. In the case of the leg, or the thigh, this factor should in a large proportion of cases determine the adoption of open operation. I still believe that in great measure this condition still holds good. In no other way can one obtain the absolute correctness of apposition and alignment which one desires. In no other way can one assure the removal of diffused blood, and the adequate freeing of muscles and tendons, which mean so much in the ultimate restoration of function. The artificial fixation of the fragments at the same time,

by plates, wire, or other means, renders the case so much more easy to nurse. Pain is at once relieved, and the period of incapacity ought to be substantially shortened. What has been said of oblique fractures of the leg and thigh I believe to be true also of most similar fractures of the shaft of the humerus, and of a considerable proportion of fractures at its upper end.

Secondly, the presence of any considerable quantity of extravasated blood. This I still believe to be an important indication for open operation, especially if it is combined with much comminution of bone, or substantial displacement of fragments. Such accompaniments are almost certain to determine the production of excessive callus around the seat of fracture, no matter how effectively without open operation these may be adjusted; and such excessive callus and irregular bony growth must necessarily greatly prejudice the recovery of function. The troublesome myositis ossificans in the neighborhood of certain fractures, especially fractures of a comminuted type, and especially where these are in the neighborhood of the more important larger joints, is probably due in great measure to the distribution of bone dust and débris—with their accompanying osteoblasts—throughout the clot and into surrounding intermuscular planes and muscular substance. The free removal of all the intervening and surrounding blood clot, and of the potentially callus-producing and bone-forming material contained in it, is most desirable from the point of view of future function.

Thirdly, failure to elicit satisfactory crepitus. This third condition or guide should require merely to be mentioned in order to justify itself. Take the case of a fracture of the shaft of the femur. If one is unable to elicit, even under anæsthesia, crepitus of an unmistakable and satisfactory character, one must assume that the fractured surfaces are not in direct contact, and in fact are probably separated from each other by non-bony material such as muscle. It is obvious that failure to remove this intervening material will not only prevent proper alignment, but will probably very materially prejudice the achievement of bony union. This being recognized, and fractures falling within this category being exposed openly, not only will the intervening material be cleared out, but the fixation of the fragments thereafter by direct means will so stabilize them that the possibility of the further interposition of soft tissues will be prevented.

These three indications for open operation and for direct fixation I believe still hold good. Speaking now, twenty years after I first suggested them, I believe they may be taken as quite good guides. They are not the only indications by any means. In particular bones, and in particular circumstances, other principles and other indications will constantly suggest themselves.

Per contra, one is bound to admit that there are, and will remain, still a considerable number of fractures, even of the long bones, such as the femur, tibia, and humerus, that will not call either for open operation or for direct internal fixation, unless as an operation of the patient's choice. Amongst these would be included many simple transverse fractures, espe-

cially those which one might term subperiosteal—i.e., simple transverse breaks of the bone, with the minimum of tearing of its periosteal covering, and hence with minimal and even no displacement.

Direct Fixation in Epiphyseal Fractures, or Fracture-Separations.—As I pointed out in my earlier paper a certain number of epiphyseal injuries call for no open operative interference. There is sometimes very little displacement, and the epiphyseal fragments are often very easily maintained in their correct relation with the diaphysis, either with or without a simple splint. In some such cases of fracture-separation in the region of the elbow in a child, little is required beyond the application of a firm bandage around the flexed elbow, and the controlling of the arm and forearms just sufficiently to prevent more than slight to-and-fro movement. The same may be said of many epiphyseal separations at the distal ends of radius and ulna, and of tibia and fibula. Provided these injuries are not dealt with haphazard, but the actual anatomical relations in each case are from the first properly appreciated, and are checked from time to time by careful X-ray examination, and where necessary the correctness of apposition secured by manipulation under a general anæsthetic, both the æsthetic result and the level of functional restoration should be satisfactory, without any operative interference of an open character.

It is a very different story, however, with those fracture-separations at the lower end of the humerus where displacement of the epiphyseal fragments is at all considerable—and it is often extreme. In such cases open operation, accurate reposition, and direct fixation are, in my opinion, almost always imperatively necessary. In no other way that I know of can one hope to obtain the satisfactory adjustment, and the restoration of full joint function that one ought to strive to obtain.

Not only so, I am quite clearly of the opinion that only by open operation and the accurate readjustment and direct fixation which are then possible, can we secure the conditions—the best conditions—for the preservation with the least possible degree of disturbance of the growth processes in that region. Without such accurate readjustment the normal growth is almost certain to be profoundly disturbed, and we shall have, with the lapse of time, the development of the ugly "gun-stock," or other, deformity which we so much dread.

In respect of these injuries, I have completely recanted from the position which I took up in 1910.[3] At that time I still held to the opinion that most fractures and fracture-separations in the region of the elbow, and particularly those involving the lower end of the humerus, could be effectively dealt with without open operation, and I was accustomed to deal with them in what one might regard as the then orthodox way, so well described and illustrated by Scudder in his textbook.[5] I was of opinion then that the main cause of limitation, or impairment, of function after these injuries was due not so much to incorrect replacement of fragments, but to their re-displacement as the result of premature and injudicious movements of the

joint. The teaching then was that movements of the joint should be begun early, and often forcible movements were carried out either with or without a general anæsthetic. I believed then, and I still believe, that these early forced movements generally did more harm than good, and my practice at that time was to replace the fragments as best I could under an anæsthetic and put up the limb, in the position of flexion at the elbow, in suitable poroplastic molded splints. The state of things was checked by means of the X-rays, and the molded splints were left on for several weeks. After their removal a limited degree of movement was permitted, but not passive or forced movement.

My position now, however, is practically a complete departure from that of 1910. I stated it pretty fully in my former paper dealing with the first five years' period,[4] and I need hardly elaborate it further here, save to say that I profoundly believe that by open operation, accurate replacement, and simple fixation of epiphyseal fragments in injuries of the lower end of the humerus, one is best able to guarantee not merely a good immediate functional result, but also the restoration and continuance of the normal growth processes which will promote the natural growth and development of the limb, and minimize the chance of the subsequent deformity which must inevitably result if epiphyseal and diaphyseal growth are disturbed, or substantially checked.

In his communication in 1910 before the British Medical Association,[6] Lane had indicated that injuries in this region had better perhaps, in most cases, be treated by non-operative means, lest the growth of bone at the epiphyseal line might be interfered with. Experience has shown me, on the contrary, that in spite of the local disturbance contingent upon open operation and direct fixation, such interference with, and disturbance of the growth processes, are less likely than where non-operative treatment is employed, and where, therefore, displaced epiphyseal fragments are not so accurately restored to their proper relations.

In my earlier paper (1922), I cited a very instructive case which seemed to confirm this view. It was that of a young lad upon whom I carried out a resection of the knee for tuberculous disease, and in the course of the operation I had the misfortune to disengage completely the whole lower epiphysis of the femur from the diaphysis. I replaced it and fixed it in position again, but I feared that the accident might lead to suspension of growth—to premature synostosis. To my surprise, this result did not follow. The bone continued to grow equally with the corresponding bone in the other limb, and that this was so, was confirmed long afterwards by comparative X-ray examination, and by periodical measurements of the limb.

I would quote here what I said in 1922.[4] It represents pretty accurately the view which I take to-day:

"I believe that if accurate re-apposition of epiphyseal centres be not brought about, the failure to do so is the very factor that will lead to the growing parts being smothered

in callus, and crushed in new irregular bone, which will effectually lead to suspension of normal growth at the epiphyseal lines.

"That nothing short of full exposure of the fracture-separation area will suffice, if accurate readjustment is to be accomplished, my now considerable experience of these

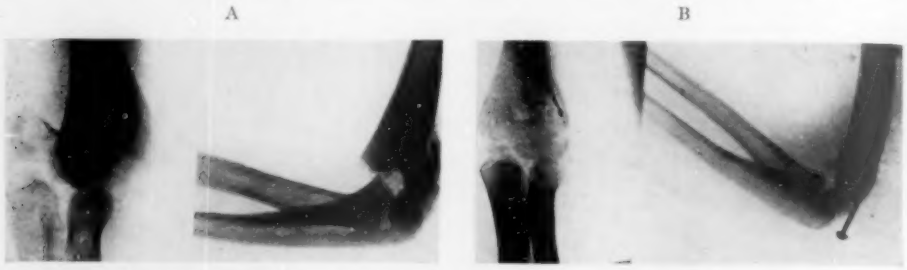


FIG. 26.—Fracture-separation, lower end of humerus, in a boy aged thirteen years. Note the gross displacement backwards of the lower (epiphyseal) fragment, with partial inversion.
Open operation. Replacement of fragments, and fixation by two pins, one of the larger type, and the other a fine "sprig." (A) Showing the displacement of fragments (anterior, posterior and profile views); (B) After replacement and fixation. (In the anterior, posterior view the larger pin has been removed. In the profile view both pins are still in position.)

cases has proved to completeness. I have found the whole lower epiphysis of the humerus so completely displaced as to be tilted in almost unbelievable fashion. I have, on quite a number of occasions, found it almost completely inverted, articular surface looking upwards, and epiphyseal cartilage downwards. [Figs. 26 (A and B)]

"I have found a fragment, including capitellum, part of trochlea, and external epicondyle, so completely tilted on its transverse axis that the articular surface of capi-

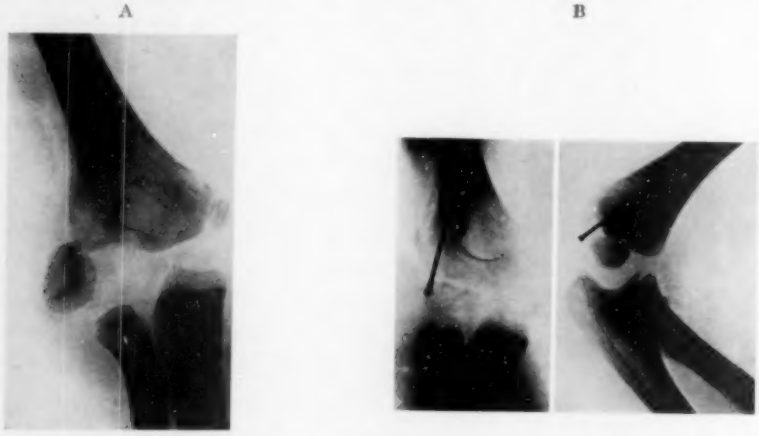


FIG. 27.—Fracture-separation of capitellar epiphysis, lower end of humerus, in a boy aged seven years. Note the gross tilting outwards of the capitellar fragment.
Open operation, replacement of fragments, and fixation by a single fine "sprig." (A) Showing the gross displacement (anterior, posterior view); (B) After replacement, and fixation (anterior, posterior and profile views).

tellum looked directly outwards, while the fractured surface rested against the head of the radius. [Figs. 27 (A and B)] We have had several instances of this.

"Further, separation of the centre for the internal epicondyle, especially if the muscular attachments to it and above it are torn away, means so considerable longitudinal displacement that nothing short of open operation and direct pinning of the fragment in its proper relation can possibly suffice. [Fig. 28 (A and B)]

"In short, the argument in favor of operative treatment of these lower humeral

epiphyseal fracture-separations—open operation, accurate readjustment, and direct fixation—seems to me sound beyond dispute."

The actual method of procedure calls for little comment. The most convenient incision in almost any type of epiphyseal displacement at the elbow, except that of the internal epicondyle alone, is one made on the external aspect of the joint, through which the radio-humeral joint is exposed, and if necessary opened; and the incision may be extended as required in an upward and backward direction. The free exposure which is thus afforded permits, in most cases, of easy readjustment of the fragments, and of the accurate reproduction of their correct anatomical relations. Once

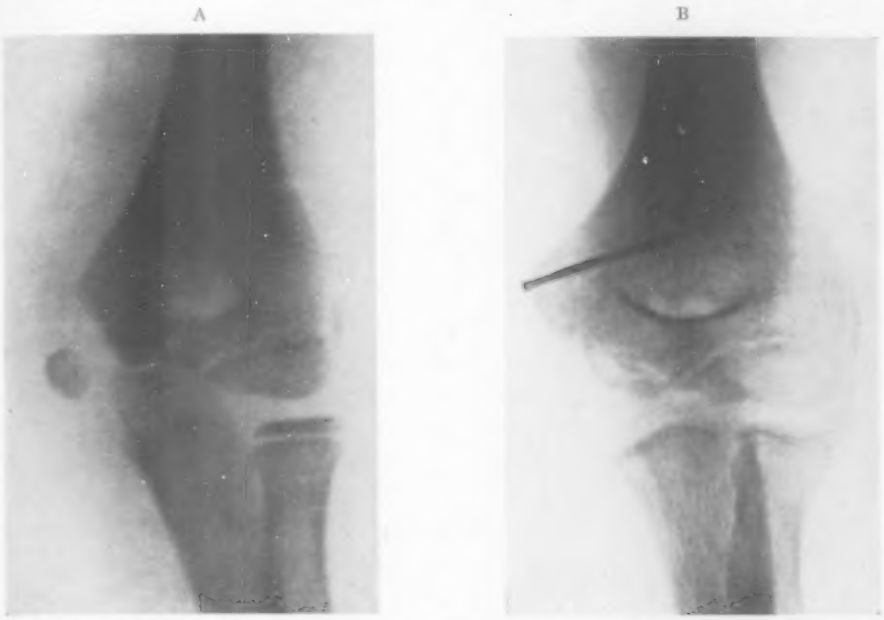


FIG. 28.—Fracture-separation of the epiphysis for the internal epicondyle of the humerus, in a boy aged ten years. Considerable separation of the epicondylar fragment.
Open operation. Replacement of separated fragment, and fixation by a single fine "sprig." (A) Showing the displacement of fragment; (B) After replacement, and fixation.

reduced, the fragments are readily fixed by one or two of the fine "sprigs" to which I alluded in the earlier part of this paper. They are readily pushed home, and are generally passed from the lower or distal fragment obliquely upwards into the lower end of the diaphysis. In some cases finger pressure alone is sufficient, while in others a few light taps with a hammer or punch may be required. The wound is closed completely, without drainage, and the limb is put up in a partially flexed position. It is placed for a few days on a simple splint, and thereafter a light plaster of Paris sheath is applied. This is removed within two or three weeks at the most, and the child is given fairly complete freedom of voluntary movement, the joint being controlled for only a short time thereafter by a lightly-applied bandage which, to a moderate degree, serves to control and prevent premature indulgence in too free movement.

As bearing out what I have said regarding the lack of interference with normal processes of growth, where this accurate replacement and fixation of fragments are carried out, I could show quite a number of examples where X-ray evidence was obtained months, and even years after, that the processes of growth were proceeding on normal lines and with normal activity. One illustrative example will suffice. Fig. 29 is a radiogram from the same case as is illustrated in Figs. 27 (A and B). This radiogram was taken a year and a half after the whole lower "capitellar" humeral epiphysis, in a boy of seven years, had been treated by open operation and direct fixation. It will be seen that both epiphyseal and diaphyseal growth had proceeded normally, and, incidentally, it will be observed that the pin, introduced through the epiphyseal fragment obliquely upwards into the diaphysis, would seem to have been carried to a considerable distance upwards within the extending diaphysis. Position and alignment were satisfactory, and functional restoration of joint movement was perfect. The boy had perfect use of his elbow, and full range of movement.

FIG. 29.—Radiogram taken a year and a half subsequent to the pinning of the capitellar epiphyseal fragment illustrated in Fig. 27. To show how epiphyseal and diaphyseal growth have proceeded normally. Note how the bone has been carried a considerable distance upwards, buried in the bone.

Direct Fixation in Certain Fractures of Phalanges, Metacarpals and Metatarsals.—In my former paper, in 1922, I described a method of axial fixation in certain cases of fracture of the phalanges and metacarpals which occasionally might be found useful. I gave a number of illustrative examples. The same method in similar circumstances would be applicable in the case of certain fractures of the metatarsals. Three cases are included in the second five years' series in which we made use of this method of axial fixation, two of these being fractures of the metacarpal, and one a fracture of a phalanx.

It is probable that most simple fractures of the phalanges will continue to be treated without open operative means, and even in the case of compound fractures, direct fixation of the fragments is not likely to be required with any frequency. There will be, however, the occasional case, perhaps somewhat neglected in the early period following the reception of the injury, in which the tilting of fragments is not readily corrected without open operation, and in which the maintenance of the correction is difficult unless some means of direct fixation is employed. We have found further, on several occasions, that a single X-ray picture has given an altogether erroneous impression of the actual position of the fragments, and even a considerable palmar displacement of one of these fragments has been liable

to be overlooked though it was mainly responsible for annulment or limitation of function. The serious disability consequent upon this displacement of sharply tilted fragments, interfering with the action of flexor tendons, has only to be mentioned to suggest the desirability of operative correction, and of the adoption of some effective means of preventing redisplacement. It is particularly desirable that operative fixation of this nature should be employed in those fractures of metacarpals or metatarsals where the bone is broken close to an extremity, for by no non-operative method is it possible to secure adequate control of the often very short articular fragment.

The procedure is simple and is easily applied. The fracture area is exposed through a short lateral incision slightly towards the dorsal aspect of the finger. The extensor tendon is drawn carefully out of the way, the fragments are disengaged, their ends are freshened, and re-alignment is established. This re-alignment is maintained by the introduction of a single fine "sprig" introduced axially from one fragment to the other, along the central canal or soft central bone, the length of the sprig employed being usually about two-thirds of the length of the broken phalanx, metacarpal or metatarsal. The head of the sprig we have sometimes nipped off with bone forceps. In other cases the sprig has been introduced from shorter fragment to longer fragment, and the head of the sprig has been left buried in the substance of the smaller fragment. It is remarkable how easy is the whole procedure, and how effective is the adjustment. The wound is closed without drainage. As I said in my former communication, "a simple (external) splint may or may not be used, according as the operator has confidence in the fixation which he has achieved, or not." In any case, the use of such an external splint should be dispensed with as soon as possible.

In the cases in which we have employed this method of axial stabilization the results have all been satisfactory. Bony union has been good, alignment has been well maintained, there has been little or no subsequent deformity, and we have been able to obtain a satisfactory functional result. Several cases in which this method has been employed are illustrated in Figs. 30 (A and B); 31 (A and B); and 32 (A and B).

Asepsis Presumed.—At this stage in the history of modern surgery it seems hardly necessary to discuss the question of the operative treatment of fractures, as if its adoption or not were to be determined by the possibility or otherwise of the avoidance of wound infection.

It is of course obvious that the surgeon who is unable to-day to guarantee, almost beyond a peradventure, the achievement of aseptic healing of the wound he must make in the operative treatment of a fractured bone, has no title to carry out such operations. But equally he has no title to perform any surgical operation for it is no more difficult to attain aseptic healing after a bone operation than after any other type of operation.

The same bogey of possible septic infection used frequently to be advanced in respect of operations upon the larger joints, and it was quite frequently maintained that it was difficult to ensure the avoidance of wound

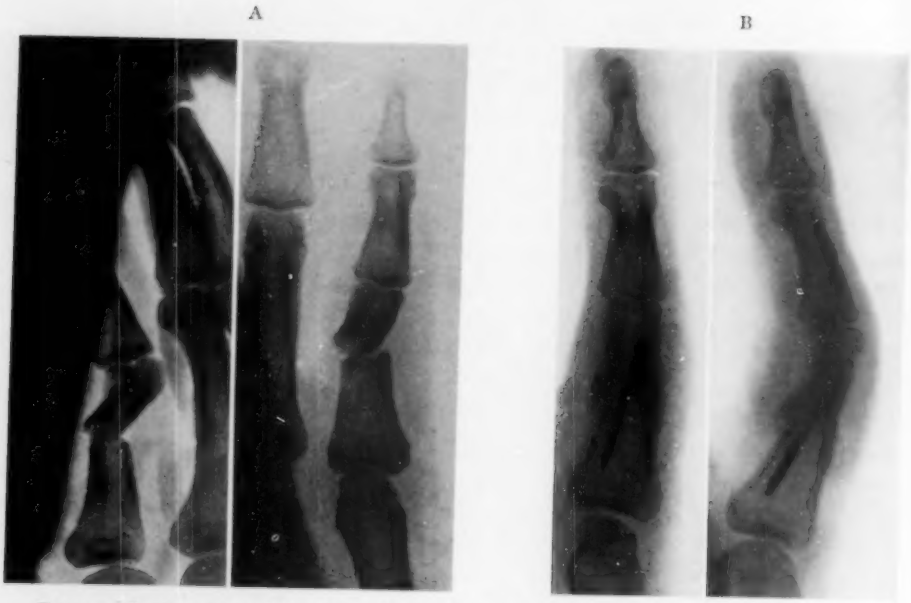


FIG. 30.—Fracture of digital phalanx in an adult male, with gross displacement and mal-union. The finger was practically useless.
Open operation. Replacement of fragments, and fixation by axial implantation of a fine "sprig." (Full recovery of function.) (A) Showing the gross displacement; (B) Showing the axially implanted "sprig."

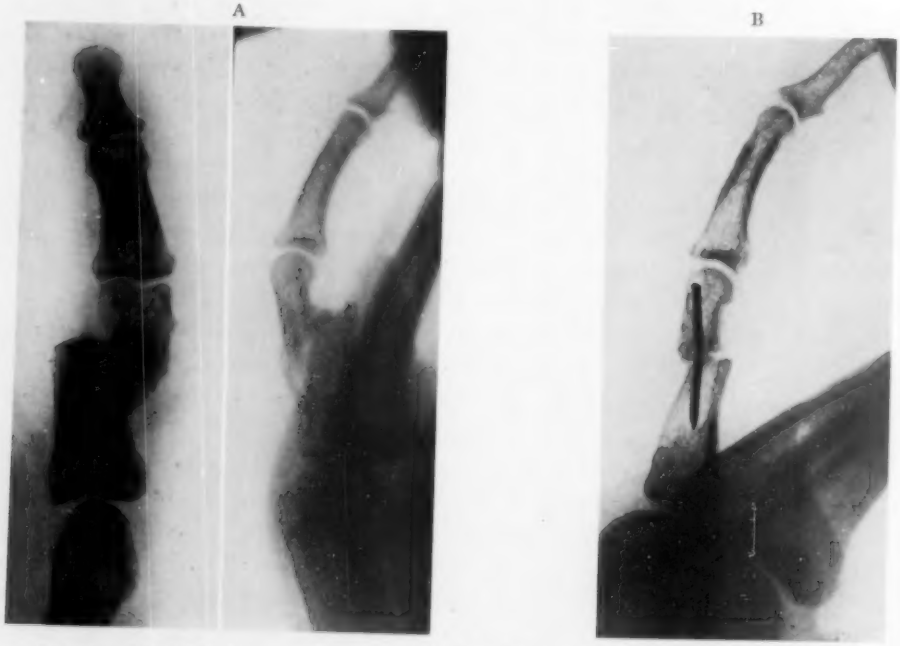


FIG. 31.—Mal-united fracture of proximal digital phalanx in an adult. Treated by open operation, replacement of fragments, and fixation by axial implantation of a fine "sprig." (A) Showing the gross lateral displacement, and also marked tilting of the proximal fragment towards the flexor surface; (B) After replacement, showing the axially implanted "sprig."

infection in these; it was said that there was little or no "margin of safety" in the case of one of the larger joints. Such an idea has surely gone by the board long ago.

It ought to have gone by the board also in respect of the operative treatment of fractures. One ought, by this time, to have reached the position when the possibility of any untoward happening of a septic nature should be practically impossible. Asepsis should be assumed, not merely as the desirable end to be achieved, but as the only possible result in the hands of the modern surgeon.

A Detail of Practical Importance in the Preliminary Treatment.—If one assumes that, in the carrying out of any open operation upon a fractured bone, the same aseptic surgical ritual shall be observed by the operator, and by all those concerned, as would be observed in the case of any other aseptic surgical operation, one ought to be able to rule out absolutely any possibility

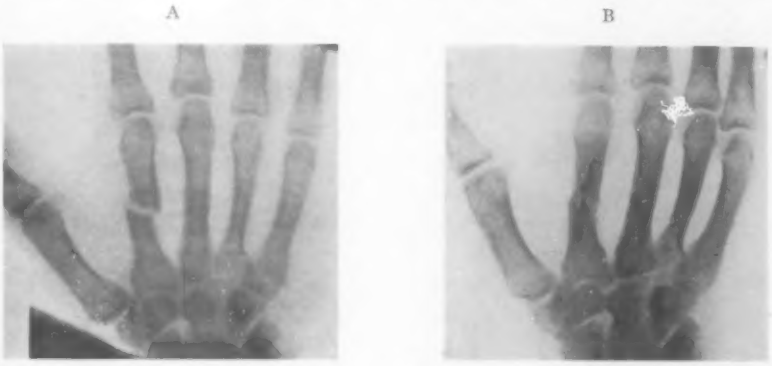


FIG. 32.—Transverse fracture of metacarpal of forefinger, fixed by axially implanted "sprig." (A) Showing the fracture; (B) The same, with the "sprig" in position.

of infection of the wound, and of the bone fragments through the ordinary channels of septic spread.

There is, however, one practical point or detail which I regard as so important that I must refer to it briefly. There is no doubt that the most potent factor in determining wound infection is the bacterial content of the skin of the area involved. Special care should be taken, therefore, to disinfect the whole area as thoroughly as is possible. But this disinfection should not be delayed until the time when operation has been determined upon. This may not be for some time after the reception of the injury, and it will be then too late. The proper time for this to be done is immediately after the patient is brought to hospital, and at as early a moment as possible after the reception of the injury. Most of us have seen the extensive irritation and vesication which may result, within even a few hours, and over a wide area of skin in the region of the damaged bone. Unless disinfection of the skin has been carried out right away there is a considerable risk of the vesicles becoming infected and even actively suppurating. The result may be the setting up of such an extensive infective process, and involving such

a wide area of skin, that a cutting operation through this area is either negatived altogether, or must perforce be delayed for some time, in the hope of getting rid of the superficial local infection.

It has been for many years now a routine procedure—an order of the day—in my surgical wards, that every case of fracture, whether simple or compound, shall be regarded as a possible case of open operation, and the first thing which must be done—it takes precedence even of X-ray examination, or the application of even a temporary splint—is the thorough disinfection of the whole area of the limb involved. By this means we feel that we are able so to assure the avoidance of any gross local infection of the skin that even should extensive devitalisation of the skin have occurred, or extensive vesication should take place, one can guarantee the avoidance locally of any gross infective disturbance, and there need be imposed, therefore, no check to the adoption of open operation at any stage when it may seem to be desirable.

When a case of fracture is admitted to my wards then, one of the first things which is done is to shave the limb over a wide area, including, and passing far beyond, the site of fracture. The whole limb is then thoroughly scrubbed with soap and water. The surface is gone over very thoroughly with spirit, and thereafter with an antiseptic lotion—generally 1-40 or even 1-20 carbolic. It is then thoroughly dried with sterile towels, and is wrapped carefully in several layers of sterile gauze. We have then no further fear of skin infection. Even should extensive vesication occur these vesicles remain aseptic, their fluid content remains clear, and they may be allowed to shrivel up by natural means, or they may be punctured if it seems desirable. But the practical point is that at any moment from the time when the patient is admitted, the surgeon may, if he choose, carry out an open operation through that disinfected skin without fear of any local infection. I would recommend the adoption of such a method as routine procedure in any casualty ward, even if the surgeon in charge is not a believer in the open operative treatment of fractures. He will avoid thereby any of those troublesome inflammatory conditions of the skin which otherwise may readily occur, and the occurrence of which, in former times, when such steps were not taken, probably determined the development of erysipelas and other local infections which complicated, and often gravely aggravated, cases even of simple fracture.

Two Cases of Serious Infection in the Combined Ten Years' Series.—It would be untrue to say—even as it would be insincere and wanting in frankness were I to allow the impression to be conveyed—that on no occasion has sepsis complicated any of our cases. But throughout the whole combined series of ten years, and through the nine years previous, there have been only two cases in which anything beyond the most trifling infection has occurred.

In one of these we lost the patient. He was an elderly man who had an extremely severe fracture of the upper end of the shaft of the femur, involv-

ing not only the upper third of the shaft, but separating, at the same time, both trochanters and splitting the femoral neck. The whole area was badly comminuted, and the fragments were widely displaced. The man's general condition was not good. He had been in poor health previously, and active operative interference was decided upon not without misgiving; but it was thought that the adoption of direct fixation might permit us to give him, at an earlier period than we could otherwise do, a certain degree of freedom which we feared to do otherwise. We had the hope that it would enable us to let him sit up in bed, and even to get out of bed at an ealier period. The operation was difficult but was successfully carried through, and the operation was well borne. For a time all went well, but a good deal of blood accumulated and a mild infective process occurred which in spite of treatment, led ultimately to his death.

The other case was that of a youth who had a severe spiral fracture of the femur about its middle. It was almost compound and there was some comminution. In the course of the operation one considerable smaller fragment became disengaged, was accidentally projected from the wound and slid across the floor of the theatre. As it was a somewhat essential fragment, I had it picked up from the floor, I scrubbed it well with a nail-brush in an antiseptic solution, and reintroduced it in its proper setting before plating the main fragments. The wound was entirely closed, and the patient pursued a normal course for six weeks when, for the first time, the wound was dressed. It appeared to be quite healed, and the limb was in excellent alignment. The sutures were removed and everything seemed satisfactory. A few weeks afterwards, however, a small fluctuant swelling appeared from which there was evacuated a quantity of disintegrated blood-clot, and subsequently the small bone fragment which was completely necrosed, had to be removed. There was in this case thereafter, and for some considerable time, a mild degree of infection which considerably lengthened not only the period of convalescence, but also the achievement of satisfactory bony union. Fortunately in the end the result was quite good, and the patient was left with a useful limb.

These two cases then may be taken as representing practically our only experience of ill-results from septic complications, and I suggest that we are entitled to regard them not as warnings against the frequent employment of open operation and direct fixation, but rather as reminders merely of the necessity for the rigid observance of the ritual of any surgical operation; as, in fact, exceptions that prove the rule. I have no doubt now that I should not have risked the replacement of the small fragment which became disengaged in the second case, and that the untoward result was really the result of an error of judgment on my part. It would have been much better to leave the fragment out altogether and trust to nature to make good the defect in her own way.

CONCLUSIONS

A critical consideration of the cases and results in the two periods of five years, and of the similar cases and results in the previous nine years, as well as our more recent impressions in the three years which have elapsed since the end of the second five years' period—i.e., *a consideration of an experience extending now over twenty years*—leads me to the formulation of a number of conclusions which I may now state very shortly.

First: Open operation, and the adoption of some form of direct fixation are not merely justified in a certain number of unusual fractures, or in a certain number of fractures with unusual displacement, but are justified in a substantial proportion of fractures of the long bones almost as a routine procedure. In certain bones, indeed, it is the surgical procedure not merely of choice, but of necessity.

Second: Open operation and direct fixation ought to be possible, and are possible, in any surgical clinic worthy of the name, and there should hardly even be the fear of possible occasional septic infection. We ought to be able to assure aseptic healing of a fracture dealt with by open operation with as great certainty as we can assure it in any surgical procedure.

Third: In the case of fractures, or fracture-separations, in the region of the elbow where there is any appreciable displacement, open operation and direct fixation afford the most favorable conditions for the early restoration of function, and for the normal continuance of growth at the epiphyseal line.

Fourth: We have not found that by the adoption of open operation and direct fixation, there has been induced any diminution in the activity and efficiency of the processes of repair. Union has not been, in our experience, in any way retarded, but rather the reverse. In our whole experience, I know of only one case in which union was substantially delayed, and of no case in which union absolutely failed. I find it difficult to understand the reports of those whose experience would seem to have been different from ours in this respect.

Fifth: There is no doubt at all that in the large majority of cases dealt with by open operation, and in which the fragments are fixed by some internal mechanical means, the period of confinement to bed—the period of hospitalization—ought to be, and is, very substantially shortened. Personally, I know that if I had to deal with two precisely similar fractures of the femur, the one dealt with without open operation and the other treated by plating, that when the stage had been reached where in both cases union might be expected to be established, I should with infinitely greater confidence allow the patient with the plated femur to get about freely. I should feel that the repair of the bone in this case, reinforced still further by the plate, justified one in permitting a degree of liberty in the use of the limb which one might hesitate to permit at such an early period in the other case; and it is clear that, the earlier such liberty can be given, the shorter will be the period

during which the muscles are left to atrophy, and the sooner may one look for effective restoration of function.

Sixth: With increasing experience I become progressively more and more convinced that correct anatomical reposition and re-alignment are the most important factors of all in the promotion of normal functional restoration. Not all the writings and teachings of the manipulative school will convince me, either that by the adoption at too early a period of massage and movement will you obtain in the end, on the average, a better functional result than in the case where operative means are taken to restore a continuity approaching as nearly as possible to perfect anatomical restoration; or, on the other hand, that we should accept the position that function alone matters, and that we need concern ourselves not at all with displacement or deformity.

Seventh: We have passed far beyond the position where open operation *may perhaps* be adopted in special cases where some unusual difficulty may seem to have occurred. We have reached the position now when it is not so often necessary to justify the choice of an open operative procedure, as to justify or explain away the failure to adopt it. I am convinced now that, by the adoption of open operation and direct fixation, I am able to offer to the patient a much surer and speedier restoration to his normal activity.

It may be not without interest in this connection if I refer to an inquiry I had in 1923 from your own brilliant exponent of the surgery of fractures, Dr. Charles L. Scudder—one of the first authorities of the day on the subject—in which, referring to my paper delivered before the British Medical Association in 1922, he expressed the wish that I might record the functional results in my cases, and the exact time the patients were away from their employment as the result of their injuries. He went on to ask the following striking question, which at first surprised me a good deal: "Have you *any* fractures of the femur back at the same job as before the accident?—treated either by operation or not?"

I may say that, following the reception of this inquiry, I made a careful investigation into our results in these cases, and I am happy to say that we have had much better results than the putting of such a question would seem to lead one to expect. As a matter of fact, more than half of our recorded cases of fracture of the femur have been able to resume their former, or similar, work; in some cases involving such exercises as climbing ladders.*

It may also be not without interest to mention that, a year or two ago, when Dr. Scudder honored me by visiting my clinic in Glasgow, and seeing there not a group of carefully selected cases, but cases in the ordinary routine of treatment and "follow-up" observation, I was able to show him a number of cases, not specially selected, which I think must have convinced him of the satisfactory and early recovery of function for which we are accustomed to look. I remember particularly one case of fracture of the femur operated on only about three months before, which Dr. Scudder himself put through

* This estimate does not apply merely to fractures of the shaft of the femur, but includes all fractures of that bone—neck and upper end, shaft and lower end. (A. Y.)

a very elaborate series of movements and tests, and in which I think he altogether failed to demonstrate any appreciable functional defect.

Eighth: The experience of these twenty years during which I have been led, in a substantial number of cases, to adopt an open operative procedure in the treatment of many fractures of the long bones, has increasingly established my confidence in the method, not only as being safe in its execution, but as affording the most hopeful outlook in respect of the early recovery of function, and the most perfect restoration of the anatomical normal.

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DISCUSSION.—DR. ASTLEY P. C. ASHHURST (Philadelphia): asked Professor Young if he could tell them what was the total number of fractures on which his operative figures were based. It makes a great difference whether one starts one's percentages with all the patients in the out-patient service as well as those in the wards, or only with the patients in the wards.

Among 5000 admissions to Dr. Ashhurst's service, Episcopal Hospital, there were 492 recent fractures (9.8 per cent. of total). Among 492 recent fractures there were 46 operations (9.2 per cent.).

Region	*Admissions*	*No operation*	*Operations*
Head and face	55	53	2
Vertebræ and pelvis	18	17	1
Clavicle	11	10	1
Scapula	2	2	0
Ribs	21	21	0
Humerus	29	27	2
Elbow	13	5	8
Forearm	22	15	7
Wrist and hand	31	22	9
Femur	76	72	4
Patella	9	5	4
Leg bones	102	100	2
Ankle	74	72	2
Foot	29	25	4
Total	492	446	46

He had gone over recently the last five thousand admissions to his service at the Episcopal Hospital. That includes all the ward patients, and a certain

number of out-patients who are sent in because they are severe fractures, or apparently irreducible. He finds that of the five thousand admissions, less than 10 per cent. were fractures, so that his experience with fractures is relatively small. Among 492 *recent* fractures (that is only the *simple* fractures, *compound* fractures and recent *simple* fractures without malunion or non-union) there were less than 10 per cent. of operations. In tabulating the regions, in the femur, he had had, among these 5,000 admissions, seventy-six patients with fractures of the femur, among whom four seemed to him to require operation. He had had 102 patients with fractures of the leg bones, among whom two seemed to require operation.

He had no objection to operation. His only object in treating fractures was to get good results.

Table II was made up seven years ago, up to May 1, 1923. He had then done 148 operations for fractures of all kinds, of which 42 per cent. were for simple fractures (i.e., *recent* simple fractures); 11 per cent. were on compound fractures; 33 per cent. were for malunion, and 14 per cent. for non-union. These cases of malunion and non-union, with *very* few exceptions, came in with the condition and were not the result of his care.

Operations for Fractures (to May 1, 1923)

Operation	*Simple*	*Compound*	*Malunion*	*Non-union*	*Total*
Plate	15	7	6	3	31
Screws	25	0	10	4	39
Cerclage	2	2	1	0	5
Suture, chromic	10	1	0	1	12
Suture, wire	0	0	0	1	1
Excision joint fragments	5	2	2	2	11
Tenotomy Tendo Achilles	2	0	0	0	2
Open reduction	3	4	0	0	7
Bone transplant	0	0	2	10	12
Arthroplasty, etc	0	0	11	0	11
Osteotomy	0	0	8	0	8
Non-reducing	0	0	9	0	9
	62	16	49	21	148

Since May 1, 1923, his percentage of operations for recent simple fractures had advanced from 42 per cent. to 50 per cent. of the total. That is to say, in the last seven years he had operated on 32 per cent. simple fractures. That is less than five a year. Two compound fractures had been operated on in the last seven years.

For malunion, fifteen operations, or 24 per cent. of the total; and 22 per cent. of the total operations were for non-union.

He had found that when he had used fixation material of screws or plates or wires, he had had to remove it eventually in about 16 per cent. of the cases. Unless there was some indication for removing it he had left it until the patient died of old age. There are patients going around now with the fixation still in place after fifteen or more years.

Of those that he had had to remove, about one-half were for incidental

Operations for Fracture (A.P.C.A.)
May 1, 1923 to May 1, 1930

Region	*Recent Simple*	*Compound*	*Malunion*	*Non-union*	*Total*
Vertebræ	1	0	0	2	3
Face	3	0	0	0	3
Clavicle	2	0	20	0	4
Humerus	2	0	0	3	5
Elbow	6	0	2	2	10
Forearm	6	0	2	3	11
Wrist and hand	0	0	5	1	6
Femur*	3	0	0	0	3
Patella	5	0	0	2	7
Leg bones	1	2	0	1	4
Ankle	0	0	4	0	4
Foot	3	0	0	0	3
Total	32 (50%)	2 (3%)	15 (24%)	14 (22%)	63

* No operations on *shaft* of femur since 1916.

reasons, operating on the patient again for something else and taking out the fixation material because it might in the future give some trouble. About a fifth were removed on account of pain, where it was thought that perhaps pain was caused by the fixation apparatus, and about a third were removed for persisting or developing infection. For instance, in compound fractures if one puts in fixation material against the bone, not infrequently it has to be removed to enable the wound to heal up, and in a few patients something like the following will happen: I plated a simple recent fracture of the radius and ulna in a girl about fourteen years of age; after two or three years she came back with an abscess over the site of plating following a severe tonsillitis complicated by cervical adenitis—evidently a metastatic localization in a *locus minoris resistentiæ*.

Dr. William L. Estes (Bethlehem, Pa.): said that in the investigation of the committee on fractures for this Association it was found that in the United States and Canada the average time of disability was decidedly longer for cases of open operation than for those treated by the closed method. If his recollection held, it is about a month's difference between. One must take into consideration, that the operation was done by operators generally over America, not by half a dozen men or two or three men accustomed to doing this work, but by surgeons generally. It was a study of over two thousand cases which brought out this point.

A second point is that although open operation produced better anatomical results, the functional results were better in non-operative cases in America. The figures showed that there were 73 per cent. of cases with non-operative treatment which resulted in good functional results, whereas with the operative cases it was 76 per cent. That, remember, is also a collection of the results of all surgeons in America, that is, all who reported. With men who are accustomed to doing this work it is a different matter, and it brings one to

the point that a surgeon who is not prepared by proper technic and proper surroundings had best hesitate unless the indication is absolute for operation.

A man who has been prepared as the reader of the paper and who is accustomed to doing this operation will find that his general result will be good.

He had found, investigating his own cases, that he was operating in 38 per cent. of the cases, and he believed that that was not an exaggeration in the clinics of men who are prepared to do this work. He again reiterated that while proper technic and proper preparation would result in much better results and much shorter disability than in the non-operative cases, in the generality of cases, with all surgeons, the result was the opposite.

DOCTOR YOUNG, in closing, said: "The statistical argument, from the point of view of the duration of the period of incapacity, is a very difficult one to meet, because, as he had indicated, the figures from one clinic may differ very widely from the figures of another. He had given his own figures. So far as he had been able to make them so, they were absolutely reliable."

Many of the operations upon fractures, especially upon fractures which have taken place some considerable time before, are operations which tax, to the utmost, the energy and physical powers of the operator. The labor is really very heavy. It is extremely unlikely that, as one advances in years, one should, at the same time, continue to employ the operative method—and with increasing frequency—in view of the excessive labor which is involved in it, unless one were really convinced of its value. It seemed to him that this argument is quite a good one, as bringing out one's real belief in the procedure.

As to the removal of the plate and screws, it does not appear that there is anything to be ashamed of in having to remove a plate, or in deciding to remove it, as a procedure of choice. Just as one removes an external splint, when it has served its purpose, so one may, on occasion, or as desired, remove an internal splint. There is no essential difference.

In the case of a fracture of the tibia, for example, one is dealing with a bone which is practically subcutaneous, and which, more particularly in a working man, is exposed to many a knock or blow on the shin. One takes a considerable risk if one decides to leave the plate in position after it has served its purpose. Its covering of soft tissues is very scanty, and it is very easy to understand how it may cause trouble. It is very different in the case of the femur, which has an abundant muscular covering to protect it from direct injury, so we very commonly remove the plate and screws in the case of a fracture of the tibia, but very seldom in the case of the femur. He knew of only one case of non-union, or of considerably delayed union, in the whole of his experience. He failed altogether, therefore, to understand how the numerous cases of non-union or of delayed union, which are reported by others, come about.

FRACTURES OF THE NECK OF THE FEMUR WITH SPECIAL REFERENCE TO THE TREATMENT OF INTRACAPSULAR FRACTURE

By Hugh McKenna, M.D.
of Chicago, Ill.

Foreword.—In presenting some phases of the treatment of intracapsular fractures of the neck of the femur, I wish to state my position before proceeding with this paper.

At present the methods giving even relatively good results seem to remain rather individual and therefore somewhat restricted in general application. Consequently, the general statistics on end-results of treatment of these fractures do not appear to have been greatly improved and therefore do not compare favorably with the results following the treatment of extracapsular fractures. For this reason the presentation of evidence pertaining to any method that may lead to a higher degree of efficiency in treatment should be acceptable. Until a standard method of procedure, giving generally a higher percentage of good end-results, is developed, the various special methods may be followed to advantage.

With these ideas in mind and without committing myself to the position of advocating the open method in any but carefully selected patients, based particularly on age and physical condition, I desire to submit some facts that I believe are of importance in the treatment of these fractures, both by the closed and open methods. I wish especially to draw attention to the following points:

1. The nutrition of the head and neck of the femur.

2. Some recent investigations of Leriche and Policard pertaining to the function of autogenous bone transplants that seem to prove scientifically their value in the production of callous formation in slow-healing fractures, thereby giving a logical reason for utilizing transplants in the treatment of some intracapsular fractures.

3. The value of the principle of impaction.

Any extensive review of medical literature pertaining to the treatment of fractures of the neck of the femur reveals a wide discrepancy in the end-results. It would appear that this discrepancy may be accounted for in part on the basis of classification, since the problem of determining whether the fracture has occurred entirely within the capsule (especially if it occurs near the attachment of the distal capsular ligament) may be impossible. In the fractures treated without operation a mistake in classification may frequently occur. In this paper the old classification of intracapsular and extracapsular is followed, not because such a division is anatomically correct, but because clinically it appears to give a workable basis for an intelligent method of

procedure in the treatment of these fractures. The term intracapsular shall be used to designate any fracture of the neck of the femur that occurs entirely within the articular capsule or at the distal attachment of the capsular ligament, while the term extracapsular shall apply to fractures entirely outside the capsule of the hip-joint. Some authors have used the term transcervical and sub-capital instead of intracapsular to describe fractures of the neck of the femur within the capsule. The objection to this classification lies in the fact that all fractures within the capsule do not fit this description, especially those that occur near the distal attachment of the

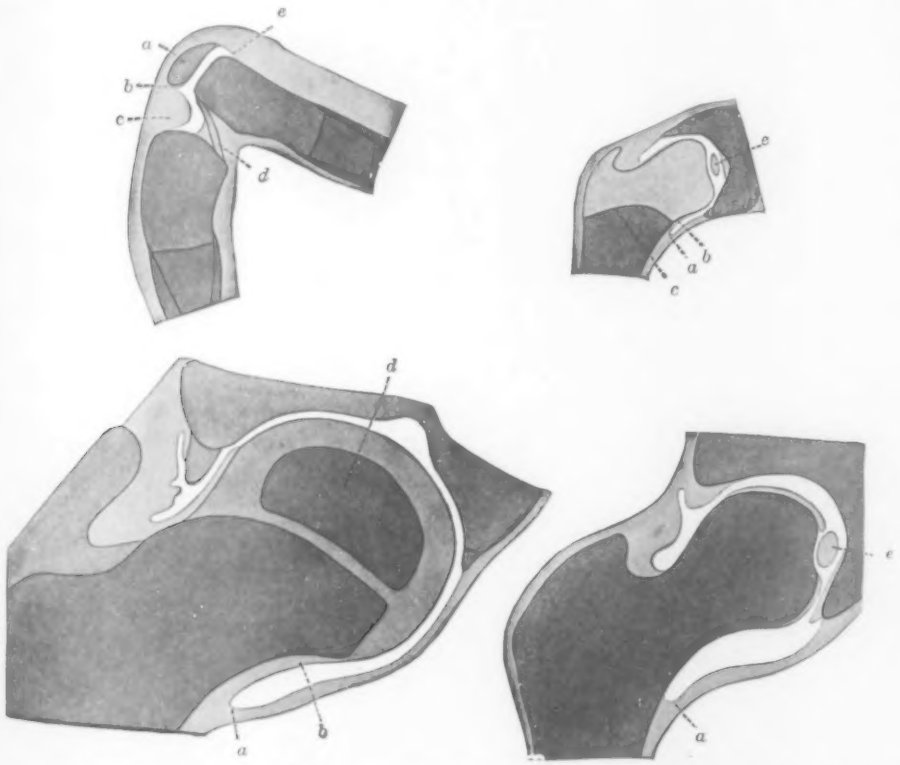

FIG. 1.—Cut taken from Keibel and Mall Embryology ("After Schulin, Archiv of Anatomie, 1879"). Cross section of a human hip-joint in a male fetus 25 centimetres in length, a female six years of age, and an adult male.

capsular ligament. Those fractures occurring within or partly within the attachment of the distal capsular ligament are not anatomically either intra- or extracapsular fractures. However, they are subjected to much the same nutritional disturbance as the transcervical type, and may therefore be classified in the same group for the purpose of treatment.

Before proceeding to the discussion of the treatment of these fractures, I wish briefly to review some points in the embryology and anatomy of the hip-joint that have a bearing upon the nutrition of the head and neck of the femur at different stages of development.

According to Keibel and Mall (vol. i, pp. 370-371), (Fig. 1), while the

embryo is growing from twenty to thirty millimetres in length, cavity formation begins between the head of the femur and the cartilaginous plates forming the floor. At this stage a fibrous band passing through the joint cavity can be made out that is to form the ligament um teres, and, according to Moser (Uber das Ligamentum Teres des Heuftgelenks) as quoted by Zemansky and Lippman (Importance of Round Ligament Vessels, Surg., Gyn. and Obstet.), blood-vessels can be determined in

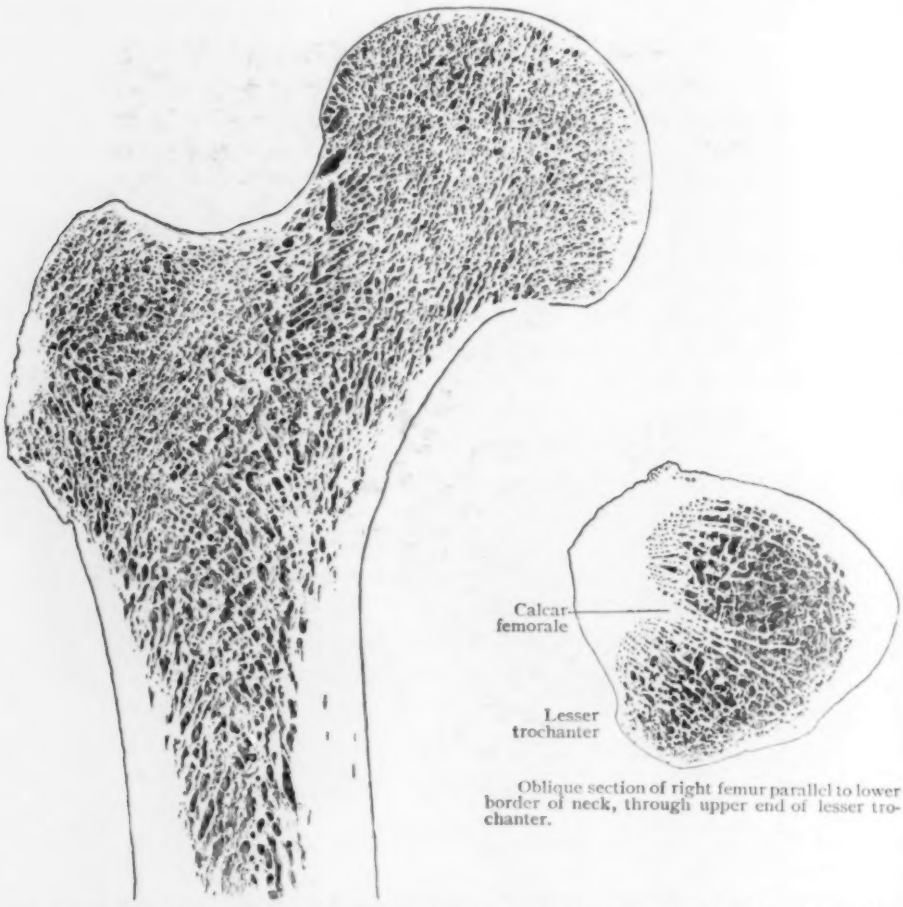
Calcar femorale
Lesser trochanter
Oblique section of right femur parallel to lower border of neck, through upper end of lesser trochanter.

FIG. 2. Cut taken from Piersol's Anatomy showing the neck of the femur to be made up principally of spongy tissue and the trabecular arrangement in two definite systems.

this structure that persist to at least the fourth year of life. How much later these vessels accompanying the ligamentum teres function in life is a disputed question, although Moser wrote: "Later, most of these vessels unquestionably atrophy." It would seem, then, that these vessels, while of nutritional importance in fœtal life and during the first years of life, are a negative source of blood supply to the head of the femur in adult life. A. Kolodney (Blood Supply of the Head of the Femur, Jour. Bone and

Joint Surg., 1925) has given a very detailed description of the blood supply to the head of the adolescent femur under four headings:

1. Blood-vessels coming from the diaphysis of the femur,
2. Epiphyseal blood-vessels,
3. Blood-vessels accompanying the ligamentum teres,
4. Periosteal vessels.

In the event of an intracapsular fracture these vessels may be considered in the light of end arteries and it will readily be seen that all of these vessels

FIG. 3.—An impacted intracapsular fracture of the neck of the femur treated by the abduction method.

may be injured, so that whether a blood supply sufficient to nourish the head and proximal fragment of the neck of the femur remains or is reëstablished may determine whether bony callous will result.

Now to pass to a consideration of the inner architecture of the head and neck of the femur as demonstrated in the accompanying picture (Fig. 2), note that the neck is made up almost entirely of spongy bone tissue which consists of two definite systems of trabeculæ, with one system beginning on the mesial side and the other coming from the lateral side of the upper end of the shaft of the femur intersecting each other at right angles. The neck of the femur is made up almost entirely of spongy tissue arranged in the

manner described, so that Koch (Laws of Bone Architecture, Am. J. Anat., vol. xxi, p. 1917) has given a mathematical analysis of the theory advanced by Wolff and Roux to the end that the anatomical arrangement is such that the minimum of material used in the inner architecture of the femur gives a maximum of strength.

This discussion of the treatment of intracapsular fractures is based upon embryological and anatomical facts that show a reason for the assumption that a nutritional disturbance in the fragments takes place in these fractures as a result of a disturbed blood supply. Fractures elsewhere in the body are not influenced by nutritional disturbances to the same degree. Professor Ernst W. Hey-Groves says, "fractures of the transcervical or intracapsular variety are of quite common occurrence in young or middle-aged patients; such fractures will never unite unless natural or artificially induced impaction of the fragments is produced." Professor Hey-Groves has reported bony union in a small series of these fractures treated in the recent state by the use of bone transplants. This procedure brings up the question whether to treat these fractures, in patients who are good surgical risks, by open operation immediately or to postpone the operation pending the development of non-union. From the standpoint of results, the ideal time to perform the bone transplant operation is from six to ten days following the fracture, before any absorption has taken place in the spongy tissue in the neck of the femur and the fragments can be brought into accurate alignment. After a number of months have elapsed following fracture and non-union is discovered, as a rule some absorption of the fragments has taken place, and while the introduction of a bone transplant at this date may give bony union, the reconstruction of the neck of the femur usually leaves some shortening and consequent deformity.

A résumé of the end-results of the most experienced surgeons who have treated these fractures by the closed method, where impaction has not occurred, demonstrates that bony union does not compare favorably with the end-results in the extracapsular type of fracture, where there has been a much lesser disturbance in the blood supply. These findings are in keeping with the researches of Leriche and Policard (Physiology of Bone) who have shown that in fractures without hæmorrhage and blood-clot, non-union as a rule follows. In my own experience in the open treatment of intracapsular fractures where the capsule was opened, no appreciable amount of hæmorrhage or blood-clot was noted, either in the joint or at the site of the fracture.

In my opinion, the ideal procedure in the treatment of these fractures is the abduction method following impaction either naturally or artificially produced. Cotton, of Boston, has produced artificial impaction in intracapsular fractures and I have observed some of his splendid results. Whitman reports a high percentage of bony union by the abduction method of treatment whether impaction is present or not. However, when one views the end-results obtained in these fractures where conventional methods have

FIG. 4.—An intracapsular fracture before reduction.

FIG. 4A.—Treated by means of an autogenous bone transplant. Picture recently taken. Patient now at hospital (August 8, 1930).

FIG. 5.—Interthrochanteric fracture before reduction.

FIG. 5A.—After reduction by the abduction method.

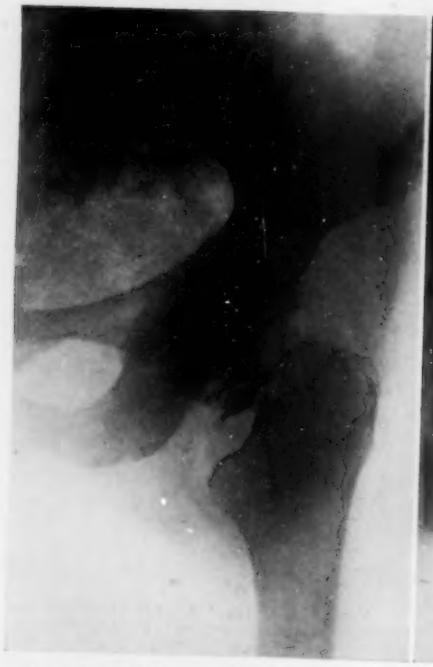

FIG. 6.—An intracapsular fracture before reduction.

FIG. 6A.—A picture over a year following treatment by the abduction method.

FIG. 7.—An intracapsular fracture of the neck of the femur reporting for treatment over two months following injury.

FIG. 7A.—Same patient showing an end-result treated by an autogenous bone transplant introduced without opening the capsule.

FIG. 8.—An epiphyseal slipping caused by an injury and reporting about nine months after accident.

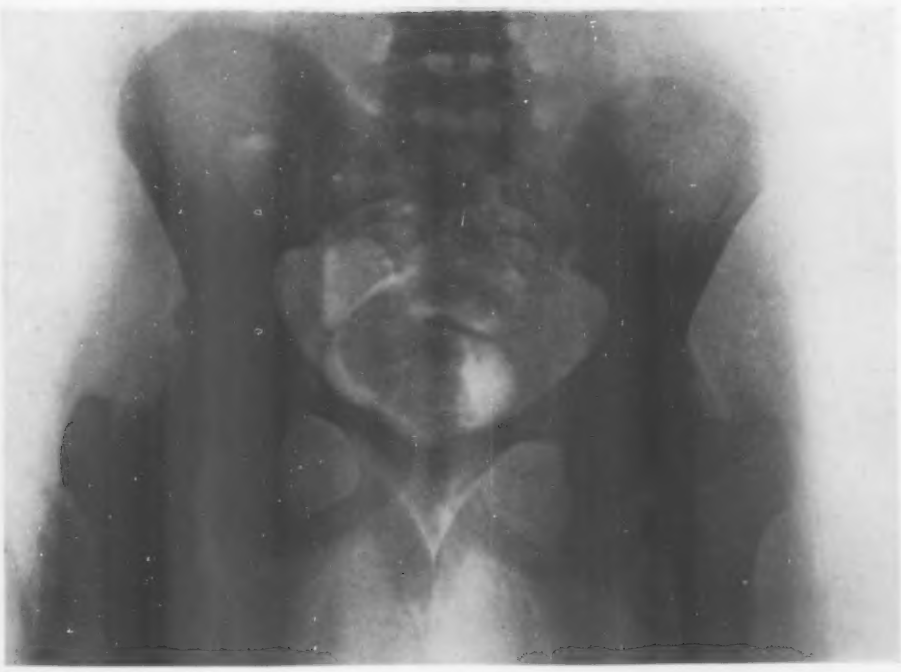

FIG. 8A.—Same, patient treated by abduction and some traction.

been followed, the percentage healing by bony union is too small to allow one to be content to follow any one method that has been outlined.

With these results in mind I began, about fifteen years ago, to treat a small number of intracapsular fractures of the neck of the femur by the open method. I selected a number of patients suffering with this type of fracture whom I considered good surgical risks. There have been only twenty operations performed on nineteen patients, but owing to a very careful selection of the physical condition of the patients, no deaths occurred and no infection followed the operation.

Mention is made of these facts because, in departing from conventional methods of treatment to a more radical line of procedure, I believe the

FIG. 9.—An end-result in the treatment of an intracapsular fracture by an autogenous bone transplant.

FIG. 10.—An end-result in an intracapsular fracture treated with an autogenous bone transplant.

surgeon should assure himself as nearly as possible that the course followed, although it may give a higher degree of assurance that a better result may be obtained, is not subjecting the patient to an unnecessary risk. In all but two operations an autogenous bone transplant was utilized to secure the fragments and was taken from the crest of the tibia. While I realize that a discussion of the function of bone transplants, in the treatment of any special type of fracture, will hold equally in considering the treatment of every fracture where its use is indicated, I wish to review some findings respecting the autogenous bone transplant that is of special importance in the treatment of intracapsular fracture.

Leriche and Policard (Physiology of Bone, Authorized English Translation by Moore and Key) are of the opinion that most surgeons hold an erroneous view respecting

the rôle of the bone transplant. They conclude that the operation of removing the transplant immediately produces its death, but, being a tissue of low vitality, does not undergo rapid change. According to these investigators, the important function of the transplant consists in furnishing calcium in the process of ossification in callous formation. Their researches respecting calcium and phosphorus metabolism are too detailed for inclusion in this paper.

Barth (quoted by Leriche and Policard) decalcified the transplant and produced only a fibrous union. Leriche and Policard further have demonstrated the manner in which the bone transplant changes in its new environment. Following the blood-clot embryonal connective tissue is formed at either end and along the lateral surfaces of the transplant. At the same time, similar changes have taken place within the transplant and new connective tissue is growing into the Haversian canals. During this period rarefaction is taking place in the fractured ends of the bone, a change that appears to result as calcium is furnished to the embryonic connective tissue in the process of ossification. Consideration of the histogenesis of the bone tissue forming the callous seems to indicate that the autogenous bone transplant should be the material of choice in the repair of these fractures where treatment is carried out by the open method.

The method followed in the treatment of these fractures must depend upon a number of factors: first, the age and physical condition of the patient; second, whether the fracture is impacted or the position shown by the X-ray is such that the fragment may be brought into good alignment; and finally, if the open method is adopted in the indicated cases special equipment is advisable and carefully controlled surgical technic is imperative.

If careful X-ray examinations are made of fractures of the neck of the femur, I am of the opinion and it has been my experience that the surgeon may determine in advance whether it is necessary to open the joint capsule in introducing the bone transplant. I have performed the operation without opening the capsule and have secured as equally good results as when the capsule was opened. I have succeeded without opening the capsule while introducing the transplant, in securing bony union in an intracapsular fracture, that had occurred over two months previously. It may be that bony union may be obtained with this plan in much older cases. I wish to call attention to the plan of introducing the bone transplant without opening the capsule as it is a much simpler and safer operation.

The L-shaped incision I have used begins at a point just below and external to the anterior inferior spine and passes back over the great trochanter and then down the outer side of the thigh. As shown in the accompanying diagram, approach to the hip-joint is made without encountering important structures. The dissection is carried down to the intertrochanteric line and just proximal to it the anterior capsule is exposed and may be opened if the surgeon deems such a step advisable.

I desire to call special attention to certain points in the technic of the operation: A dowel opening is made through the compact portion of the shaft of the femur by means of an electrically driven drill and the opening is continued through the neck into the head by means of a hand drill, in order to minimize the amount of injury to the spongy tissues of the neck. The hand drill gives a better sense of direction in approach to the proximal

FIG. 11.—Intracapsular fracture treated with an autogenous bone transplant.

FIG. 12.—An intracapsular fracture treated with an autogenous bone transplant.

FIG. 13.—An intracapsular fracture approximately six weeks old.

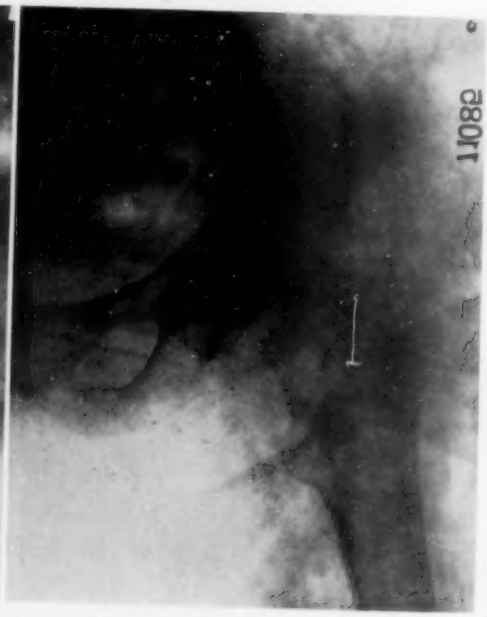

FIG. 13A.—Same, treated by means of an autogenous bone transplant without opening the capsule.

fragment and head of the femur. The only type of bone transplant used has been from the patient's tibia and contained the periosteum. The transplant has been removed with a minimum of trauma and driven into the previously prepared dowel opening in the neck of the femur. I have placed

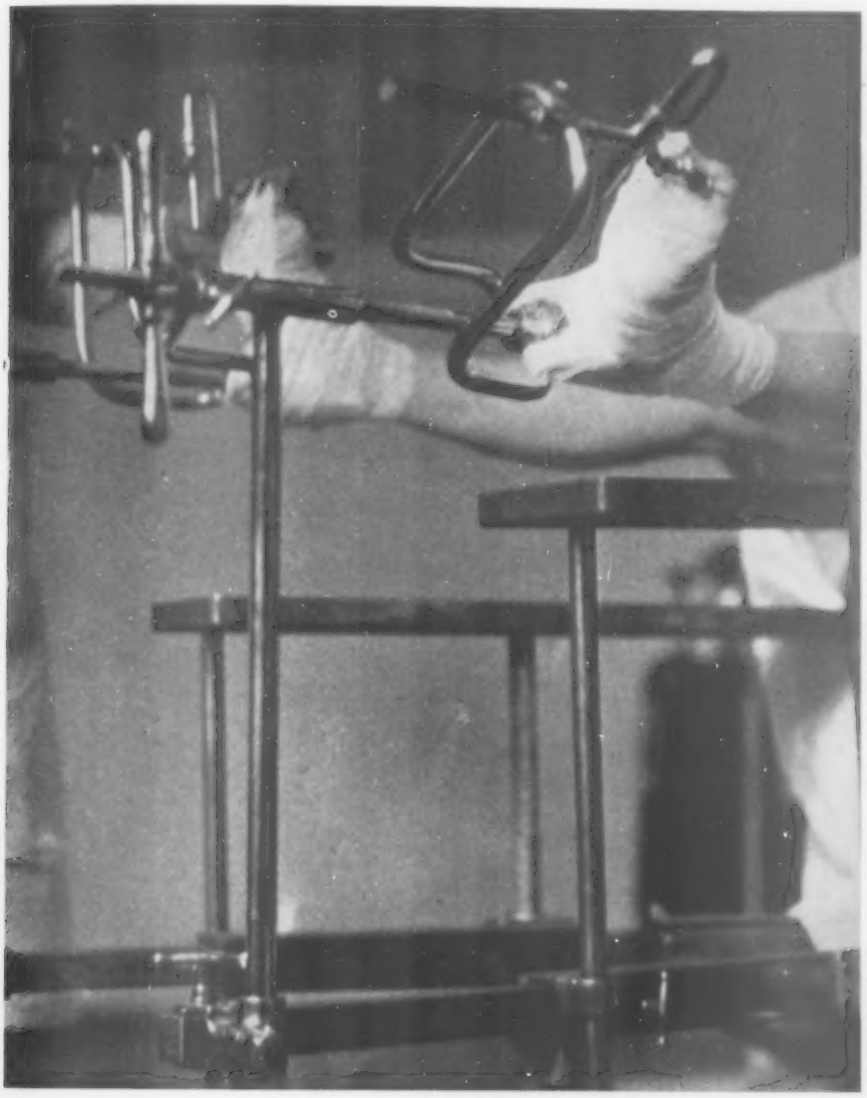

FIG. 14.—The author's table showing the foot piece with the left foot in external rotation.

much importance on producing an artificial impaction of the fragments after the transplant has been driven into place. Special equipment in the treatment of fractures is very essential. I have worked out a special table (Fig. 14) for the conduct of this work, a late model of which is shown in the accompanying picture, with a special heel piece and adjustable foot

attachment; internal and external rotation can be accurately controlled. This I believe to be one of the very important factors in the successful treatment of these fractures.

In reviewing the operations performed in this series, I have the following comments to make:

In the first two operations steel nails were used to secure the bony fragments. In the remainder autogenous tibial bone transplants were utilized. One patient developed a pulmonary embolism in the third week following operation, but after a somewhat stormy convalescence recovered. A second patient had a limitation of motion in the knee of the affected side, not being able to flex the knee only slightly over ninety degrees, although in the repair of this fracture one of the best anatomical results was obtained. In the first two operations, where steel nails were used, non-union resulted in both instances. In one of the fractures treated in a recent state with the fragments held in excellent position by means of a tibial bone graft, non-union resulted. In a tuberculous patient treated for late non-union, the operation being performed twice about a year apart, only fibrous union resulted.

Owing to my inability to reach some of the remaining patients following discharge from the hospital at the end of four months, it is impossible to record the final results in all of them. Then, too, the number was too small to give very conclusive information. However, this paper was written to show the following points in the treatment of intracapsular fractures of the neck of the femur:

1. The open method of treatment may be carried out in carefully selected patients without undue risk.

2. Some fractures may be treated without opening the capsule, thereby simplifying the operation.

3. The physiology of bone repair seems to show that the autogenous bone transplant accelerates callous formation in fractures with poor blood supply and therefore may be used to advantage in the repair of certain intracapsular fractures of the neck of the femur.

Discussion.—Doctor Kellogg Speed (Chicago) remarked that the important thing in fractures of the neck of the femur is the mortality and the uncertainty of the result in those that survive. One never knows whether the bony union is lasting or whether the head is going to necrose and die later on. There are three points in connection with the treatment: first, the blood supply of which the essayist spoke; second, the position of reduction of the fracture; and third, the bony union which is acquired which must be supported by a brace until the vitality of the head is assured. The blood supply in the head and neck of the femur comes from the ligamentum teres, from the diaphysis with penetrating branches from the epiphyseal vessels and penetrating vessels from the periosteum.

The essayist said that in operating upon these fractures he had not seen blood in the joint or about the bone. If he had looked at the bone itself he might have seen it. Doctor Speed presented a lantern slide which showed

a fracture of the femur, impacted and apparently healed clinically with a large amount of extravasated blood running down into the trochanter and upper diaphyseal portions of the bone, perhaps with penetration into the head. This fracture was over three months old before death occurred, a fracture of the shaft having occurred at the same time and completely healing in the interim. He then showed a second slide made from an impacted fracture, remarking that the impacted type is supposed to give the most favorable prognosis and yet one sees in this slide from the X-ray of a specimen the great amount of atrophy in the trochanteric portion of the bone, the rather increased density from the neck toward the head which may indicate a shutting out of the blood supply and an aseptic necrosis beginning in the head.

A third slide was from a specimen of the neck of the femur four months after fracture, apparently healed clinically. The head may be dead; it is rather dense. Notice the large amount of atrophy in the trochanteric area corresponding somewhat to that hæmorrhagic portion shown in the first specimen, and yet there seems to be some union at the neck. Would that stand use and wear if the patient had survived after these four months?

A fourth slide represented the normal healing fracture of the neck of the femur about fourteen months after the fracture. The bone has regained much of its vitality, the trabecular arrangement supporting the head has been reëstablished so that weight-bearing now without support is entirely possible.

A fifth slide was from a woman who was immobilized in plaster for only eight weeks and then allowed to walk. The use of her leg caused a breaking down of the healing attempt in the bone. This was followed by a succession of slides illustrating various phases of the conditions that may attend fracture of the neck of the femur.

Dr. Daniel F. Jones (Boston) said that at the Massachusetts General Hospital they had been particularly interested in intracapsular fractures of the neck of the femur because they had been unable to get bony union in more than 60 per cent. of the cases. He mentioned that Doctor Smith-Petersen, of the Orthopedia Department, has developed a nail which, in the few cases in which he has used it, has given excellent results. The nail is made up of a head somewhat over one-half inch in diameter. The body of the nail, which has the same circumference, consists of three rather thin strips of metal united at one edge and radiating at an equal distance apart. The trochanter and neck are exposed, the fragments placed in proper alignment, and after measuring the distance from the trochanter to the articular surface of the head, a nail of the proper length to engage the head is driven in through the trochanter and neck into the head up to the articular surface. These patients are put to bed with only light traction for two weeks, after which they are allowed to move the leg freely about the bed, a great boon to the older patients. The nail seems to accomplish two things. It holds the neck and head in apposition, and the flanges make a channel into the head from the neck through which blood-vessels make their way to supply the head. If this does not occur, it is difficult to see why the head does

not atrophy more often. Doctor Smith-Petersen has proceeded slowly with the use of the nail because the Fracture Service at the hospital has been rather opposed to it, but his results have been excellent. He has, Doctor Jones believes, operated upon twenty-five cases there with excellent results in 85 per cent. of the cases.

DR. HUGH MCKENNA remarked finally, respecting the time of fixation, he believed these patients, whether treated by the open or closed method, should be placed in the abduction position for a period of sixteen weeks. The important principle to be carried out, in the open operation, even though the autogenous transplant is used, is the impaction of the bony fragments.

PYLORIC OCCLUSION FROM SULPHURIC ACID

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of Toronto, Canada

from the surgical clinic of the university of toronto

The taking of corrosive fluids by persons, either by mistake or with suicidal intent, is quite common. In the majority of cases it produces death, and the pathological condition is revealed only at post-mortem. In this case we were able to demonstrate the pathological condition, which was confined to the stomach, and relieve it by operation.

Joseph G., aged thirty-eight, married, a healthy Russian plumber, on the afternoon of December 3, 1929, drank by mistake for gin, three ounces of commercial sulphuric acid. Immediately discovering the mistake, he went to the Toronto General Hospital, and within twenty-five minutes had his stomach washed out, but, unfortunately, was allowed to go home without any instructions as to further treatment. The next day he commenced to vomit blackish fluid, and continued to do so frequently for about three days. At the end of a week he was able to take some nourishment, and then worked for two weeks, eating small amounts. At the end of the third week he commenced vomiting at night large quantities of undigested food mixed with black, foul-smelling material.

He went to a local clinic where an X-ray examination was made, and was informed that there was no obstruction to the outlet of the stomach, and that he would be all right on a diet which they prescribed. However, the vomiting becoming almost continuous, he consulted Doctor Anderson a few days later, and was sent by him into the Wellesley Hospital January 2, 1930; that is, thirty days after having taken the acid.

At this time he had complete obstruction of the pylorus, was dehydrated, breath loaded with acetone, with the smell of putrefaction. Analysis of the stomach content showed absence of free hydrochloric acid, but presence of combined acid, and a large amount of blood. Bile was never present.

January 9 a jejunostomy was done eight inches below the duodeno-jejunal flexure, following the technic of Moynihan. The patient was now fed very satisfactorily, and rapidly improved. The stomach was washed out twice a day for four weeks, and when the return fluid became less offensive, indicating that the sloughing of the mucous membrane had ceased, a barium meal was given. This showed the œsophagus to be free of obstruction, the meal entering the stomach in a normal manner. The pyloric end did not fill nor was there any evidence of anything passing through the pylorus at the end of twelve hours. There were peristaltic waves passing irregularly over the greater and lesser curvatures and the content was about a pint.

With these findings, and the patient now being in a much improved condition, a gastroenterostomy was done February 14.

The stomach was normal in color, the cardiac portion distended, and on tracing it over to the right it was seen to narrow abruptly in the antrum to a width of about an inch. The pylorus was completely occluded by an inflammatory mass three inches in length, extending from the pyloric antrum into the first part of the duodenum. The second portion of the duodenum was firmly adherent to the gall-bladder. This latter structure was distended, grayish-blue in color, and, on first appearance, seemed necrotic. The duodenum throughout the first and second portions was very much narrowed. The liver and pancreas were normal. The mucous membrane of the stomach was hæmorrhagic

in spots, alternating with normal areas and fibrotic areas. A section of all coats was removed which showed the mucous membrane to be desquamating; the glands were regular in size, shape and outline, the interstitial tissue showed marked congestion. The mucosa received showed no evidence of ulceration, but œdema and congestion.

For a week the patient was fed through the jejunostomy tube, his stomach being washed out twice daily. At the end of this time, as there was no gastric retention and the washings were clean, the jejunostomy tube was removed, the opening blocked with gauze, and feeding begun by mouth. The skin was kept protected with vaseline so that there was no irritation from the slight jejunal leak. At the end of three weeks it had closed completely.

The patient, at the present time—three months after operation—is perfectly well, and has resumed work. He is following the routine prescribed for all cases of gastro-enterostomy.

Lord Moynihan[1] states that an examination of the museum specimens and a search into the records show that in cases in which an intensely irritating fluid has been swallowed, accidentally or with suicidal intent, the parts most affected are lips and mouth, pharynx, and the first inch or more of the œsophagus, the lower end of the œsophagus immediately above the cardiac orifice, and the pylorus and pyloric antrum. The greater part of the œsophagus escapes serious damage, though patches of ulceration, or even gangrene, may be distributed throughout it. So far as the stomach is concerned, the worst injury is inflicted on the pylorus, but in severe cases the whole mucous membrane may be affected.

C. B. Keetley likened the appearance of the pyloric portion of the stomach in one of his cases to "a small sausage"; of a second he said, "the pylorus was thickened and so contracted that it would only just admit the closed blades of a pair of polypus forceps"; and of a third that there was "thickening and a very tight stricture of the pylorus."

Thirst is intolerable, and vomiting is an early and constant symptom; even when a very small quantity of fluid is taken, it may be ejected at once or in a few minutes.

Treatment.—In all cases it is of the first importance to see that there is complete abstention from food. When food is given, the process of ulceration is quickened, the ulceration spreads, and gangrene in more or less extensive patches occurs. The chief attempt should be directed to keeping the scalded surfaces sweet and clean. Mouth-washes, sprays, gargles, frequent mopping of the ulcers with gauze swabs, all are useful in helping to insure cleanliness. Two and a half per cent. solution of glucose should be given interstitially.

The safest course would appear to be an early resort to surgery. By means of some operative procedure the feeding of the patient can be insured for a sufficient time to allow healing to take place in the ulcerated patches.

Where the lesion is confined to the pylorus, as was the case with my patient, jejunostomy followed by gastroenterostomy gave us an excellent result and would appear to best meet the indications. Where the lesion is

confined to the œsophagus, then a gastrostomy might be sufficient, but even in this case the jejunostomy would answer the same purpose. If the pylorus is affected as well as the lower end of the œsophagus, a jejunostomy should first be done, to be followed later by a gastrojejunostomy.

Hoebeke and Brasseur[2] describe a case in which the mouth was not burnt, but in which there was evidence of œsophageal and stomach lesions, clearing up without operative treatment.

The cases reported by Chavigny and Laborde,[3] Davezag and Micheleau,[4] and Dujarier and Rosenthal,[5] were fatal, death ensuing within a few hours.

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ALKALOSIS DUE TO PYLORIC STENOSIS SIMULATING NEPHRITIC URÆMIA

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"La fixité du milieu intérieur est la condition de la vie libre et indépendante."
—Cl. Bernard.

Only recently have we come to possess a knowledge of the mechanism and phenomena of alkalosis sufficient to appraise its clinical importance and to bring the realization that by an understanding and use of the factors involved, the clinician may reduce both his morbidity and mortality. The credit for this may, without Chauvinism, be given chiefly to American observers. Our knowledge has grown step by step mainly through investigations into (1) the cause of tetany; (2) the toxic manifestations of intestinal obstruction, particularly high obstruction; and (3) the attention focused upon derangements of plasma structure found in the more frequent condition of acidosis.

Kussmaul, in 1869, described gastric tetany, but for years only fanciful explanations were offered for its occurrence, such as desiccation of tissues, the absorption of toxins from the stomach, and obscure nervous influences. To complicate the situation, the re-discovery of the parathyroids and experimental work by Gley, in 1891, led to the further finding that removal of the parathyroids was followed by tetany. Wilson, Stearns, and Janney (1915), using the newer methods of blood chemistry, elaborated by Lawrence Henderson, Van Slyke, Folin, and others, investigated tetany parathyreopriva and found a marked increase in the alkalinity of the plasma as shown by increased CO_2 combining power. McCann (1918), confirmed this finding and showed that gastric tetany presented the same abnormality of plasma reaction in more marked degree. MacCallum and his co-workers obtained like results in gastric tetany and noted also the extreme fall in blood chlorides which he ascribed to the loss of hydrochloric acid in the vomitus. This loss of acid he believed to be the cause of the alkalosis. He and Voegtlin had already noted another chemical abnormality in parathyroid tetany, namely, disturbance of calcium metabolism, and had found that convulsions could be controlled temporarily by supplying calcium to the blood. They found that tetany, or its minor manifestations, such as twitchings and hyperexcitability of the motor nerves, could be produced by the intravenous injection of large amounts of carbonate or bicarbonate of soda, which indicated the importance of the alkaline imbalance of the blood.

In the meantime, especially during the last fifteen years, a large amount of investigation was being made upon intestinal obstruction. The obvious toxic characteristics of the condition focused efforts upon the discovery of a

toxin or toxins of more or less specific character. Two main schools of thought developed, one which held that the toxin was the result of heightened bacterial activity and absorption in the obstructed loops, the other which sought for the toxin in the perverted digestive and metabolic processes in the obstructed intestine leading to formation and absorption of highly toxic split protein products. Leaving aside this controversy, which is not yet settled, an important by-product resulted. Through all this work, frequent reference was made to an early series of experiments by Hartwell and Hoguet (1912) who found that the toxic effects of obstruction upon experimental animals could largely be prevented if sufficient fluids were administered, in the form of salt solution, to prevent dehydration. The emphasis was placed upon the fluid. The rôle of its sodium chloride content was not considered, as the salt was used in order to make the solution isotonic for purposes of injection. We have seen, in the light of later developments, that while the fluid was important the sodium chloride was even more so.

The clinical fact that high obstruction is more rapidly fatal than low obstruction led to much search for a toxin-bearing area in the upper intestine. This fact has now been correlated with the early and severe chemical imbalance caused by high obstruction.

In 1914, Tileston and Comfort had noted a high non-protein nitrogen in the blood in cases of experimental intestinal obstruction. In 1923, Haden and Orr in three cases of gastroenterostomy, complicated by failure of function of the stoma with severe vomiting, found all the important chemical abnormalities of the plasma previously noted; namely, high nitrogen retention, low plasma chlorides and high CO_2 combining power. They found that efforts at restoration of the normal chemical structure of the plasma gave strikingly beneficial results. This appears to have been the first clinical correlation and application of the growing conception of alkalosis. They followed these observations by experiments upon intestinal obstruction in general and showed that severe alkalosis is a characteristic of this condition. Obstructed animals given plain water died more quickly than those receiving no fluids at all. Obviously, to increase the water intake and thereby the abnormal loss of certain elements of the blood through vomiting and other eliminative channels only aggravated chemical imbalance. This is the reason for the remarkable observations of Hartwell and Hoguet which were for years unexplained. By giving salt they were maintaining the chemical balance of the plasma, thus protecting these animals against the damaging effects of alkalosis. Haden and Orr suggested that chlorides had a detoxifying effect upon the harmful substances absorbed from the bowel in obstruction. Whether such a direct chemical antagonism is present cannot be definitely stated, at present, but it seems more likely that we have to do with two separable noxious factors in intestinal obstruction; namely (1) the absorption of toxins; and (2) chemical imbalance resulting in alkalosis, kidney damage and consequent retention of both endogenous and exogenous toxins.

Important clinical observations were now added by Brown, Eusterman, Hartman, and Rowntree (1923). In eleven cases studied in the Mayo Clinic, they noted as the result of organic obstruction, anatomic or physiologic stasis in the duodenum, a characteristic clinical picture and changes in blood chemistry. Apparently being influenced by the prevailing ideas as to the existence of an absorbable toxin under these conditions they designated this as a duodenal toxæmia. The clinical picture consisted of (1) vomiting of large amounts of thin, serous, bile-stained fluid; (2) dehydration with

florid complexion, high hæmoglobin, low blood-pressure and asthænia; (3) tetany-like manifestations; and (4) features of shock and uræmia. The blood showed low chlorides, high CO_2 combining power and high blood urea and creatinin. They called attention particularly to the renal damage as evidenced by albumin, casts, blood nitrogen retention and decreased excretion of phenolsulphonephthalein. McVicar, in 1925, extended this symptom complex to all cases of high intestinal obstruction showing that a similar toxic effect and identical blood changes occurred. He showed that severe alkalæmia may exist without tetany and that tetany may be anticipated when CO_2 combining power of the plasma passes 100 volumes per cent.

In the meantime, the work of the chemists had given a basis for understanding the phenomena of chemical imbalance of the plasma. It had been found that health demanded the maintenance of a remarkably constant reaction of the blood. Expressed in terms of hydrogen ion concentration (pH) the normal variation fell between 7.3 and 7.5. Normally, the blood reaction is slightly alkaline. In the oxidizing processes of metabolism large amounts of carbonic acid and smaller amounts of lactic, phosphoric, sulphuric and other acids are being formed. In pathological states oxybutyric and diacetic acids are produced. Under the ordinary conditions of life the reaction of the blood tends to become acid. This tendency is counterbalanced by the removal of excess acid through the lungs and excretory organs, through metabolic destruction of certain acids and by absorption of neutralizing basic substances which are constantly taken with the food. Likewise, a surplus of base may be neutralized by the acids produced or they may be excreted through the kidneys and intestinal tract. In order to accomplish this transformation and transportation within the body, use is made of certain labile substances which are known as buffers. The most important of these are hæmoglobin and the phosphates and bicarbonates. The regulation of blood reaction is accomplished chiefly by the latter owing to the ease with which carbonic acid may be blown off through the lungs in the form of its acid radical, carbon dioxide, or in case of need, it may be held in the blood for combination with base to form base bicarbonate, the reaction of which is weakly alkaline. The mechanism is remarkably efficient but it may fail because of respiratory abnormalities or because the accumulation of acids or alkalies within the body may surpass its regulatory power. Van Slyke has shown that in addition to the normal balance there are eight possible abnormal states. Alkali may be deficient or present in excess. In either case it may be compensated or uncompensated. If compensated the blood reaction remains normal though the blood plasma structure is altered: if uncompensated, the reaction of the blood shifts in accordance with the reaction of the substance present in excess. The same is true of the acid regulator carbon dioxide which may be in excess or deficient in amount and in each instance may be compensated or uncompensated. All these abnormal conditions have been produced experimentally and it is probable that all may occur in man under certain conditions. The attention of the clinician was directed first toward acidosis, *i.e.*, compensated and uncompensated alkali deficit. These are seen most often in diabetes and nephritis, in the

former instance being due to the accumulation of diacetic and oxybutyric acids, the products of incomplete carbohydrate metabolism, and in nephritis to the failure of elimination of the non-volatile acids formed during ordinary cellular metabolism. For a better account of the chemistry involved one should consult the descriptions of Gamble and Hartman or the more detailed scientific expositions of Van Slyke and Wilson. The clinician should acquire a certain familiarity with the underlying principles since it is not easy to furnish a rule of thumb for application to therapy in all cases. We have seen the abuse of sodium bicarbonate as a routine post-operative measure and it is not at all well known that the ketone acids may be present in the urine even in alkalosis, thus leading to the administration of alkalies which aggravate the condition.

If we may judge by the literature it would seem that the clinical importance of alkalosis has received insufficient attention. Hardt and Rivers, in 1923, called attention to the dangers of over-alkalization in the medical treatment of peptic ulcer. They found that ill effects were more likely to occur in patients whose renal function was impaired, doubtless owing to the difficulty of excretion of the excess of alkali in such cases. Cases were encountered in which the excessive use of alkalies caused severe renal damage, uræmia and, in some instances, typical tetany. Case reports and clinical papers have been contributed to the subject by Harrison and Perlzweig (1925), Ellis (England, 1926), Bothe (1926), Larson and Pulford (1928), Andrews and Bump (1928), Rathery and Rudolph (France, 1928 and 1929). The Italians have contributed a number of clinical papers.

The renal phenomena associated with alkalosis are interesting and important. Apparently there is a nephrosis which tends to be severe. There is evidence of damage to the glomeruli and renal epithelium as shown by albumin, casts, and not infrequently red blood-cells in the urine. Decreased excretory power is reflected in low elimination of phenolsulphonephthalein and rapidly mounting retention of blood nitrogen. In certain cases the picture is that of uræmia. Tucker, in 1922, reported eight cases of uræmia following gastroenterostomy. The first four cases died; the fifth developed tetany, for which he was given calcium chloride and salt solution with happy results. We can now realize that this type of uræmia is due chiefly if not entirely to alkalosis. A few non-operative cases of alkalosis simulating uræmia have been reported by Rowntree, Ellis, and Rathery and Rudolph. In some cases the underlying cause was not suspected and the patient incorrectly treated by eliminative measures, no attention being paid to the chemical imbalance. The small amount of data available show this to be a highly fatal procedure.

The following case is an example of the ease with which this error may occur and the importance of treating such cases from the standpoint of chemical imbalance.

Case.—On October 10, 1929, a man, H. C., aged forty-one, was admitted to the Presbyterian Hospital, in Philadelphia, complaining of drowsiness, loss of weight and

vomiting. Seven weeks previously he had been admitted to the Presbyterian Hospital under the care of an internist. At that time he was semi-stuporous, irrational and occasionally vomited profusely. On that admission he was successfully treated under a diagnosis of nephritis, uræmia and general visceroptosis. This diagnosis was based upon a history of somewhat similar attacks covering a period of ten or fifteen years; a pallid, somewhat anæmic appearance similar to that of chronic nephritis (Hæmoglobin 78 per cent.; red blood cells, 4,100,000; white blood cells, 9,200); high blood urea nitrogen (117 milligrams per 100 cubic centimetres); persistent low specific gravity of the urine rarely rising above 1010; the presence of considerable albumin with granular casts and red blood-cells in the urine; a low phthalein elimination (on the fifth day, first hour, 300 cubic centimetres, 12 per cent.: second hour, 60 cubic centimetres, 16 per cent). The reaction of the urine was alkaline. The blood-pressure was low (108 systolic; 68 diastolic, and on successive examinations frequently below 100 systolic).

On forced fluids and eliminative measures, he responded quickly, passing large amounts of urine, eliminating the blood urea nitrogen, the clinical condition improving *pari passu*.

It was obvious that he had gastric retention, and his digestive history was interesting. After a severe attack of whooping cough at about fourteen years of age, he began to have stomach trouble, which continued up to the present. In the beginning he had pain after meals but for many years pain had not been a conspicuous feature. Instead he had discomfort and a feeling of fulness whenever he indulged heartily in food or liquids. He had found that he could make himself comfortable by emptying his stomach and frequently used the stomach tube for that purpose.

Seven years previously a gastro-intestinal X-ray examination had been made from which a diagnosis of gastroptosis was made. No evidence of ulcer was detected at that time, it was said. Physically, he was the typically ptotic type.

On this occasion also, after he had improved, an X-ray study was made with the following conclusions: "Visceroptosis of sufficient degree to account for symptoms of fairly severe grade. Part of six-hour retention can be thus explained. The fact that there is a large irregular duodenal cap with a constant deformity strongly suggests adhesions or ulceration, probably the former."

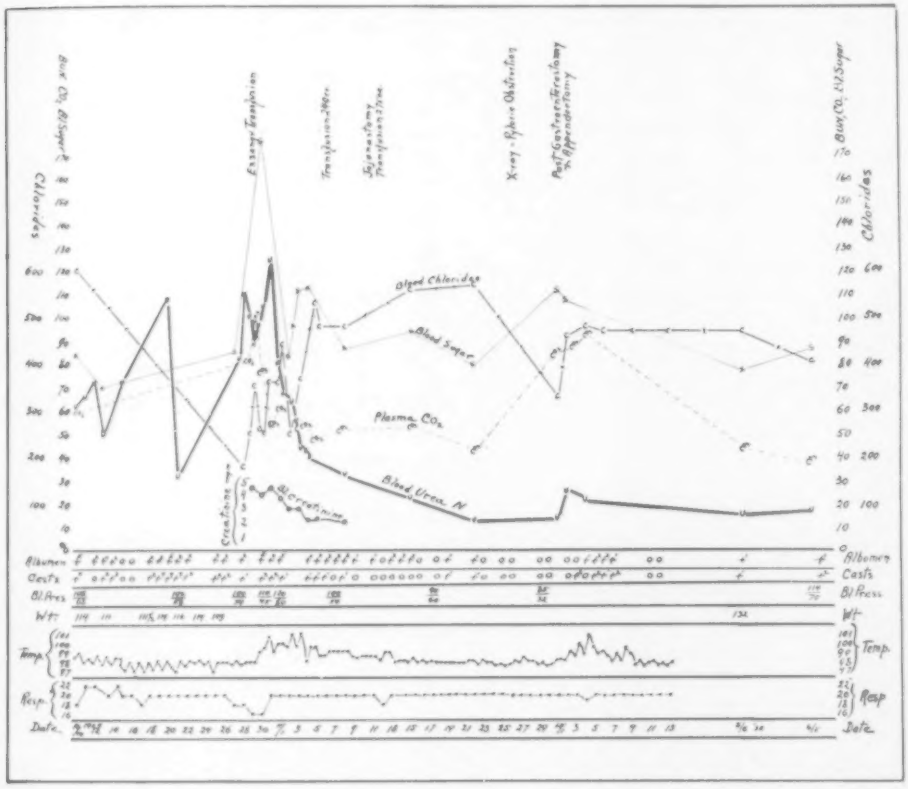
I saw him at this time with Doctor Phillips and in view of his obvious improvement and the doubt as to an organic condition other than ptosis, it was decided to send him home to follow a careful dietetic and general regimen adapted to the treatment of ptosis.

In a month he had gained twenty pounds and felt very well. Then he began to have trouble with his stomach. He would vomit at night, and frequently relieved himself with the stomach tube. In a week he was readmitted with symptoms of uræmia. Again his blood urea nitrogen was high (62 on admission, 68 next day, 76 next day). The urine was alkaline, specific gravity 1010, and contained many granular casts. Subsequently red blood-cells appeared. Phenolsulphonethalein elimination in two hours was 23 per cent. Forced fluids and eliminative treatment similar to that employed on his former admission failed. He became unable to retain anything by mouth and required lavage for gastric dilatation. On the seventeenth day, he was irrational with a blood urea nitrogen of 84.7. He was very restless and exhibited twitching of the muscles but at no time was carpo-pedal spasm or the definite evidences of tetany observed. Trousseau's and Chvostek's signs were never elicited. At this time (October 28) I saw him and was impressed with the similarity of his condition to that observed in miscellaneous surgical cases in which alkalosis was present. Blood chemistry at this time showed blood urea nitrogen, 100; chlorides 180; CO_2, 98 volumes per cent. The low chloride concentration (one-third normal), and high CO_2 confirmed

the idea. (It is worthy of note that he had been kept on a salt-free diet because of his nephritis.)

It was decided to concentrate all treatment upon the restoration of chemical balance.

October 29.—Continuous hypodermoclysis with normal salt solution was given. Five hundred cubic centimetres of 2 per cent. salt solution and 250 cubic centimetres 10 per cent. glucose solution were administered intravenously. Ten cubic centimetres of 10 per cent. calcium chloride solution were given with the intravenous solution. The following day (October 30) the urine, which had fallen to a small amount voided incontinently, had increased to over 3000 cubic centimetres, blood urea nitrogen was 98, chlorides 363, sugar 176, CO_2 73. He regained consciousness but was still semisturporous. With a view to reducing the urea concentration in the blood an exsanguination



transfusion was done, about 200 cubic centimetres of dark viscous blood being withdrawn and replaced by 400 cubic centimetres. Under this treatment two days later:

November 1.—Conscious, voiding voluntarily, blood urea nitrogen 68, chlorides 432, sugar and CO_2 normal. A curious phenomenon was noted. Although nothing was given by mouth a continuous gastric hypersecretion occurred causing dilatation of the stomach and requiring siphonage, which was carried out by the Jutte tube. As much as 2500 cubic centimetres of dark bile-stained fluid was withdrawn daily. This militated against restoration of the normal sodium chloride balance and caused a rise in blood urea nitrogen and a fall in chlorides. On the second day (November 3) it was noted that the blood chlorides had fallen to 280. Blood urea nitrogen had dropped to 57, sugar and CO_2 still normal. Two per cent. intravenous salt and 10 per cent. glucose was given again in addition to normal salt solution by hypodermoclysis. The following

day (November 4) the blood chlorides had mounted to 396, blood urea nitrogen was again reduced to 46.2.

On November 6, one week after beginning this treatment, the blood chemistry had reached normal except for the blood urea nitrogen, which was still moderately elevated: blood urea nitrogen 33.95, chlorides 528, CO_2 46 volume per cent. A second transfusion was given this day. As the chlorides approached normal, gastric hypersecretion diminished. It was impossible, however, to induce the stomach to empty through the pylorus.

Water and fruit juices were tried but after a period of hours could be withdrawn with some excess, evidently from the stomach and duodenum. For five days this continued, the patient being sustained by parenteral fluids and another transfusion.

November 11.—A jejunostomy was then made under local anæsthesia. By this means it was possible to supply fluids and nourishment by bowel. This was continued for two weeks, nothing whatever being given by mouth. Each day about 200 to 300 cubic centimetres of bile-stained fluid were withdrawn from the stomach. At this time to determine the condition of the pylorus 250 cubic centimetres of barium mixture were given by mouth but none passed through the pylorus in six hours.

November 30.—Being convinced that there must be mechanical interference, it was decided to explore, which was done under spinocaine. This anæsthetic was selected in spite of the low blood-pressure (at this time about 90 systolic) since it was felt that the danger of circulatory collapse could be met more safely than the after affects of general anæsthesia upon such a debilitated individual. Whether this was good reasoning or not, at any rate, after administration of the preliminary ephedrin, the blood-pressure began to rise, reaching 108 in ten minutes. A blood transfusion was started simultaneously with the operation. The blood-pressure continued to rise and reached 128 in twenty minutes, and the patient's condition gave no concern throughout the operation, which lasted fifty-five minutes.

A typical pyloric stenosis was found, evidently the result of an old, healed, duodenal ulcer. The lumen would probably not have admitted an ordinary lead pencil. A posterior gastroenterostomy and appendectomy were performed.

Here again a curious phenomenon was noted. It was felt that even should the gastroenterostomy fail to work for a time, it would be a simple matter to carry the patient along by his jejunostomy which was still present and through which he had been entirely sustained for over two weeks. However, the attempt to use the jejunostomy after operation led to the discovery that under the new conditions all food and fluids which were introduced into the jejunum were promptly reversed into the stomach and there accumulated until the stomach became distended and required relief by lavage. It was again necessary to resort to hypodermoclysis and intravenous administration of saline and glucose. On the third day it occurred to me to reintroduce into the jejunum what was being lost through the stomach. Since that time I found in Wilkie's Murphy oration before the American College of Surgeons that he had done a somewhat similar thing in a case where he had made two enterostomies. He suggested that possibly there is some principle elaborated in the upper intestines which is required for stimulating normal peristalsis in the lower portion. In any event, after introducing the gastric contents secured by lavage into the jejunostomy opening, reverse peristalsis soon stopped and all was smooth sailing thereafter.

December 19, 1929.—The patient left the hospital three weeks after operation. Since that time he has gained twenty-three pounds. Except for occasional heartburn, he has felt entirely well.

Reëxamination May 5, 1930, by Dr. John Eiman.

Blood-pressure: systolic, 114; diastolic, 70.
Blood urea nitrogen—18.2 milligrams per 100 cubic centimetres.
Sugar—88 milligrams per 100 cubic centimetres.

Creatinin—1.8 milligrams per 100 cubic centimetres.
Chlorides—402.7 milligrams per 100 cubic centimetres.
Plasma CO_2—38. Vols. per cent.

Urinalysis

	Morning	Evening
Specific gravity	1017	1015
Reaction	acid	acid
Albumin	trace	trace
Glucose	none	none

Microscopical: Morning specimen, three to six hyaline, light granular and coarsely granular casts per high power field. Few leucocytes. No erythrocytes.
Evening specimen, six to eight finely and coarsely granular casts per high power field, many cylindroids. Several clumps of leucocytes. No erythrocytes.

Phenosulphonephthalein:

	Amount	Dye
First hour	40 cubic centimetres	18 per cent.
Second hour	40 cubic centimetres	15 per cent.
Totals	80 cubic centimetres	33 per cent.

There is still evidence of renal damage and insufficiency. He shows some oral sepsis which may be playing a rôle. This will be cleared up and its influence determined.

Comment.—The relation of the kidneys to alkalosis deserves more extended study. Dr. John Eiman, Pathologist of the Presbyterian Hospital in Philadelphia, believes that a specific and recognizable type of glomerular damage and nephrosis is associated with this condition. It is certain that a high degree of irritation and actual cellular damage are the early consequences of this form of plasma abnormality. Its effects may closely simulate uræmia. As a matter of fact, the result is a form of uræmia and the depression of the nervous system due to urea poisoning may counterbalance the hyper-excitability of nerve structures characteristic of alkali tetany, thus obscuring a clinical diagnosis.

Conversely, when renal impairment already exists the liability to both acidosis and alkalosis is increased owing to the faulty eliminative function, which is one of the important aids in maintaining chemical balance of the blood. While the common change in nephritis is in the direction of acidosis, it must not be overlooked that when conditions tending to produce alkalosis are present the shift towards alkalinity is likely to be exaggerated. There is then a vicious circle. The kidneys are further damaged and function more impaired. In acute cases the outcome is speedily fatal unless the fault be detected and repaired. In recurring or chronic alkalosis a permanent glomerulonephritis may possibly result.

The reaction of the urine may and frequently does remain acid in severe alkalosis. This is usually due to the fact that owing to the loss of body

fluids containing base as well as acid, there is an absolute deficit of base even though it preponderates in the blood. The acid solutes of metabolism pass the kidneys more readily, causing the urine to give an acid reaction.

It is important also to realize that there is no necessary parallelism between the ketone acids and the normal acid regulators of the blood. The finding of diacetic acid and oxybutyric acid in the urine does not preclude the existence of alkalosis and the decision to administer alkalies should not be based upon such finding alone.

Blood chemical examinations are essential to the diagnosis and accurate therapy. The chief indices are the CO_2 content of the plasma and the blood chlorides. The pH is less delicate since it may not be affected so long as the alkalosis is compensated. If we except the alkalosis which is due to excessive administration of alkalies or to hyperventilation, we may say that under clinical conditions alkalosis results from diminution of chlorine in the blood which thus frees base to unite with bicarbonate to form alkaline substances. The obvious therapy, therefore, is to restore chlorine, which may readily be done by giving sodium chloride through the available avenues. Abundant normal salt solution not only counteracts dehydration but replaces the lost chlorine. Hypertonic solution given intravenously should be employed in severe cases. Given familiarity with the conditions likely to be complicated by alkalosis, its development is best prevented by liberal infusions of salt solution. Result should be checked by blood chemical estimations. The use of glucose is of great value in protecting protein against destruction, supplying energy and aiding elimination. Blood transfusions have shown their clinical utility.

CONCLUSIONS

Alkalosis, though less common than acidosis, is a definite and important condition demanding clinical recognition and specific treatment. It may be suspected especially in conditions of profuse and prolonged vomiting, and in obstructive states, mechanical or physiological, involving the stomach and upper intestinal tract.

Symptomatically it shows itself by (1) vomiting, usually profuse, often by gastric hypersecretion and dilatation; (2) dehydration with asthænia and reduced blood-pressure; (3) restlessness, irritability, nervous twitchings and, in certain cases, typical tetany; (4) in the later stages, stupor and coma resembling uræmia of nephritic origin.

The urinary findings are those of acute glomerulonephritis and phenolsulphonephthalein elimination is diminished. The blood chemistry is diagnostic, the essential changes being diminution in chlorides and increase in CO_2. Nitrogen retention is also an early and significant sign.

Treatment consists in restoring the chemical balance of the blood plasma. In severe cases intravenous therapy is indicated and should accompany, or, if possible, precede urgent surgery.

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Discussion: Dr. Donald Church Balfour, of Rochester, Minn., said that he had seen the exact counterpart of the patient described by Dr. Pfeiffer and had seen the same spectacular results come from the use of salt and glucose intravenously. A point he would like to make, however, is that before this serious toxemia develops there are usually signs which will permit prevention of this toxemia. Any patient who shows any evidence of gastric retention, should be put in the hospital to immediately determine whether there are any changes in the blood urea or the carbon dioxide combining power or the chlorides, and if there are changes, no matter how slight they may be, the patient is given salt and glucose intravenously.

In this way we have practically eliminated any serious cases of toxemia from high gastro-intestinal obstruction.

THE SERUM TREATMENT OF BACTERÆMIA DUE TO HÆMOLYTIC STREPTOCOCCUS

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FROM THE SELINA B. MACILHENNY RESEARCH FUND OF THE PRESBYTERIAN HOSPITAL OF PHILADELPHIA

The treatment of septicæmia or, as it is better known today, of bacteræmia of whatever origin remains a problem which to our minds still awaits a satisfactory solution. As a clinical condition, and aside from its occurrence as a terminal phenomenon, it presents a rather frequent and sufficiently urgent complication which oftentimes exceeds in severity and danger the original lesion. This applies especially to the commoner surgical infections, particularly the bacteræmias of staphylococcic and streptococcic origin. There is no consensus of opinion today as to the value of any one method of treatment. In this study we have confined ourselves mainly to the subject of blood-stream infections due to the hæmolytic streptococcus. Bacteræmias due to other types of streptococci or the staphylococcus present entirely different problems.

The numerous contributions in recent years on the treatment of bacteræmia by chemotherapeutic agents have attracted great attention and have more or less diverted the attention of surgeons from the older method of serum treatment. Aside from the surgical treatment of the primary focus, the importance of which is well recognized, the usual practices of today include four different methods of attack. These include general supportive treatment, chemotherapy, blood transfusion, and finally serum therapy. From our observations in various clinics the last seems to be a poor fourth. This attitude seems somewhat anomalous in view of the recognized progress which has been made in the control of streptococcic infections in other fields, notably in scarlet fever and erysipelas.

The recent withdrawal by the American Medical Association of antistreptococcic serum from the list of New and Non-official remedies is a significant indication of the trend of surgical opinions and practice. The questionnaire submitted by Novak[1] to the heads of twenty-five clinics in the United States showed, in the majority of instances (sixteen), that experience with antistreptococcic serum had been disappointing, and one surgeon was apparently ignorant of its existence. Others (eight) found it to be of some value. We are not convinced that unqualified rejection of serum treatment is justified. Our personal experience has been quite to the contrary.

With regard to the other methods of treatment already mentioned, in any case the surgical control of the primary focus, if demonstrable, by elimination, sterilization or drainage, supersedes in importance all other procedures. Without such control all other measures are sure to be futile in the great majority of instances. Reference has been made to general supportive treatment. This is too often taken for granted in the treatment of all prolonged

infections. The accelerated metabolic rate attending fever makes increased demands on stored carbohydrate, and, if this be not maintained, the fats are called upon and oftentimes their combustion is incomplete and results in the formation of acetone bodies. Likewise, failure to maintain the water balance is a common error. Anorexia and gastric irritability often interfere with administration of fluids and nourishment; if this be the case, one should utilize the bowel, subcutaneous or intravenous routes.

Blood transfusion and the perfection of methods which render its use safe and convenient, as well as its undoubted value in certain cases, help to explain its popularity. Its non-specific antigenic action is also of value both by itself and as an adjuvant to other methods of treatment. One must not overlook the danger of overloading the circulation and throwing serious strain on the heart by too large and too frequent transfusions. With regard to chemotherapy, we believe the results obtained up to the present time by the intravenous use of chemotherapeutic agents have been disappointing to the majority of conservatively minded surgeons. However, we would not belittle the attempts to develop bacteriotropic chemotherapeutic agents. It is possible that in the future this problem will be solved along these lines. The brilliant results obtained in the treatment of syphilis have stimulated immunologists and chemists the world over to duplicate this success in the control of bacterial infections, but no reagent so far developed has, in our opinion, met the test in its application to clinical practice in the types of infection under consideration.

The material presented in this paper consists of forty-three cases of streptococcus hæmolyticus infection in which the blood cultures were positive. This number is small but is fairly representative of cases as they occur in general hospital practice. The great majority of the cases tabulated as treated

TABLE I

Streptococcus hemolyticus bacteræmia cases

Primary Focus	Group I Died without serum or too small amounts while in extremis	Group II Recovered without serum	Group III Died with serum	Group IV Recovered with serum	Total
Abortion	4	1	2	5	12
Puerpural Sepsis	0	0	0	1	1
Otitis Media, Mastoiditis or Sinusitis	4	2	0	4	10
Respiratory Tract	2	0	0	1	3
Infection of Extremities or Cellulitis	6	2	2	4	14
Ulcerative Carcinoma of Uterus	1	0	0	0	1
Undetermined	2	0	0	0	2
Total	19	5	4	15	43

Recovered without serum treatment 5 of 24 cases or 21 per cent
Recovered with serum treatment 15 of 19 cases or 79 per cent

by serum have been under our personal observation and control, either as surgeon or consultant. The majority of contributions on this subject have been based upon studies of series of cases from gynecological and obstetrical services. In our series, however, this is not the case. A large proportion of cases was observed in the general surgical service, in addition to those from the gynecological and obstetrical, and otolarnygological wards.

In an evalution of any method of treatment of this condition it is necessary to recall the underlying pathological processes. All of this has been so clearly brought to our attention in the splendid article presented before this Association five years ago by Dr. Walton Martin[2] that it hardly needs repetition in detail. We must appreciate that it is not the problem of an infection in a closed system such as the circulation. The presence of infected thrombi in the circulatory tree forms an exception. It is the intermittent or continuous discharge of bacteria into the blood-stream; the reactions of the natural defense mechanism of the body, manifested either by stimulation or exhaustion of the hæmopoietic system; the rôle played by the reticulocytes; the action of the non-specific immune substances in the body fluids; and in uncontrolled cases the development of secondary foci, extensive hæmolysis and toxæmia with its attendant changes in the parenchymatous organs.

In our own observations in cases of bacteræmia due to pyogenic organisms we have been impressed with the necessity of differentiation between these cases which are characterized by what we call the "shower type" of infection, from a "massive invasion" of the blood-stream by bacteria. In the shower type of blood-stream invasion positive blood cultures are obtained either before or immediately after surgical intervention for an acute primary focus, such as drainage of an infected hand or the removal of infected thrombi from the lateral sinus. In such cases the natural defense mechanism is usually capable of destroying the bacteria without further therapeutic measures. The further invasion of the blood-stream is checked by whatever surgical method has been employed. Any additional therapeutic agent used at this time naturally is given credit for the sterilization of the blood-stream. In this type of infection when cultures are made on blood agar plates, only a few colonies of organisms are found.

In cases illustrating the "massive type" of invasion, blood-culture plates reveal hundreds of colonies of bacteria per one cubic centimetre of blood, and the surgical treatment of the primary focus does not lead to the abatement of the symptoms. Under such conditions of overwhelming infection the natural defense mechanism is rapidly exhausted and the chain of symptoms already described follows as a natural consequence. This is aside from the disputed question as to whether or not bacteria multiply in the blood-stream itself.

The two types of blood-stream invasion by bacteria are best illustrated by what is so often seen in cases of osteomyelitis, although in these cases the blood-stream is frequently sterile by the time the patient comes under the observation of the surgeon, the stage of "shower invasion" having already

passed. In neglected cases a "massive invasion" takes place from the localized infection in the bone. In a few instances the period intervening between the primary "shower invasion" and the secondary overwhelming "massive invasion" is very short or may be entirely absent. In any event other foci rapidly develop either in other bones or connective tissue, lungs, joints or the viscera, depending in some degree on the specificity of attraction manifested by different strains. This illustration of our point is furnished by a surgical lesion, osteomyelitis of hematogenous origin due to staphylococcus aureus. The cases which we are including in this paper are of different origin. While we have been interested in the problem of both types of bacteræmia we have found it necessary to attack the problem of staphylococcus infection from another angle, due to failure to obtain a satisfactory bacteriocidal serum for the staphylococcus aureus.

Some explanation seems necessary for the attitude of the surgical profession toward the use of serum therapy in streptococcus hæmolyticus bacteræmia. Such explanation is not far to seek. It is now a good many years since the streptococcus serum has been available for use. Nor is there any question of the failure of the old monovalent serum to reduce mortality. There are a number of strains of hæmolytic streptococcus which react differently to biological tests, consequently, the use of a polyvalent serum is imperative. It is with the consideration of the modern polyvalent serum that we are concerned in this study.

Group I.—Nineteen cases of bacteræmia died either without serum treatment or received insufficient amounts of serum while *in extremis*. This group emphasized the importance of administration of sufficient amounts of serum

TABLE II

Group I. Died without serum or received too small amounts when in extremis

No.	Name	Age	Diagnosis	Serum	Transfusion	Mercurochrome
1	O. K.....	36	Acute respiratory infection	0	0	0
2	S. B.....	50	Respiratory infection	0	0	0
3	M. J. N...	38	Acute abdomen	0	0	0
4	M. C.....	36	Abortion	0	0	0
5	M. R.....	31	Abortion	0	0	0
6	J. L.....	26	Abortion	0	0	0
7	B. E.....	48	Ulcerated carcinoma of uterus	0	0	0
8	D. R.....	23	Infected knee joint	0	0	0
9	W. H. W..	66	Crushed hand	50 cc.	0	0
10	J. M.....	36	Mastoiditis	0	0	0
11	G. M.....	20	Abortion	100 cc.	0	0
12	E. N.....	7	Meningitis	0	0	0
13	L. W.....	68	Infected leg	0	0	0
14	E. C.....	64	Gangrenous foot	0	0	0
15	H. O'R...	10	Otitis media	0	0	0
16	H. C. O...	33	Buerger's disease	90 cc.	0	0
17	A. V. T...		Infected hand	0	0	0
18	G. W.....	22	Pelvic cellulitis	0	0	0
19	T. Z.....	30	Infected hand	100 cc.	0	0

early or before marked degeneration of parenchymatous organs takes place.

Group II.—Five cases in this group recovered without the use of serum. This group deserves particular attention: it shows that a number of cases of streptococcus hæmolyticus bacteræmia do recover without any immunologic or chemotherapeutic treatment. Cases No. 4 and No. 5 belong definitely in the so-called "shower invasion" group and the blood-stream became sterile after establishment of satisfactory drainage of the primary focus. Cases No. 1 and No. 2 also recovered without the use of serum. In Case No. 1 an infected thrombus was removed from the lateral sinus and in Case No. 2 mastoidectomy was done but phlebitis of the lateral sinus must have existed. In both patients the temperature varied from 101° to 105° for forty or fifty days respectively. Administration of serum might have shortened the period of morbidity.

TABLE III

Group II. Recovered without serum

No.	Name	Age	Diagnosis	Serum	Transfusion	Mercurochrome	Remarks
1	A. J. D...	9	Acute mastoiditis, thrombosis, lateral sinus	0	0	0	Mastoidectomy. Removal of thrombus from lateral sinus. High temperature for forty days
2	P. P.....	14	Acute mastoiditis	0	0	0	Mastoidectomy. High temperature for fifty days
3	P. P.....	24	Abortion	0	0	0	High temperature for thirty days
4	J. W.....	54	Cellulitis of hand	0	0	0	Incision and drainage
5	Dr. W....		Cellulitis of hand	0	0	0	Incision and drainage

Group III.—Consists of four cases, all of which died in spite of large doses of antistreptococcic serum. Two of these cases were autopsied. Case No. 1 showed extensive septic thrombi in the veins of both broad ligaments, particularly the left and a septic thrombus in the left ovarian vein extending into the left renal vein and projecting into the vena cava. This patient was given, before the serum treatment was begun, 250 milligrams of mercurochrome. This produced uncontrollable bloody diarrhœa, but no beneficial influence on the general condition of the patient. Intravenous administration of 550 cubic centimetres of serum in three days did not change her condition, neither did a blood transfusion of 500 cubic centimetres. Autopsy on Case No. 4 revealed a perforated uterus and acute generalized fibrino-cellular peritonitis. There was no autopsy in Case No. 3. Shortly before death, however, there were definite evidences of peritonitis.

Group IV.—Includes fifteen cases, all with a "massive" blood-stream invasion by the hæmolytic streptococcus. In all fifteen cases massive doses of serum were used, and all of them recovered. Surgical measures were

TABLE IV

Group III. Died with serum

No.	Name	Age	Diagnosis	Serum	Transfusion	Mercurochrome	Remarks
1	L. M.....	42	Abortion	550 cc.	500 cc.	250 mgs.	Autopsy—Abscesses in wall of uterus. Thrombosis of veins of broad ligaments, left ovarian and renal veins
2	T. M.....	31	Cellulitis of leg	240 cc.	0	0	
3	A. T.....		Abortion	360 cc.	0	0	
4	M. D.....	21	Abortion	250 cc.	0	0	Autopsy:—Ruptured uterus, peritonitis

employed in the treatment of the primary foci where indicated. Blood transfusions were given in some cases.

In our experience, polyvalent antistreptococcic serum, or, for that matter, any other serum or chemotherapeutic agent, does not exert any beneficial

TABLE V

Group IV. Recovered with serum

No.	Name	Age	Diagnosis	Serum	Transfusion	Mercurochrome	Remarks
1	C. H.....	25	Abortion	650 cc.	0	0	
2	B. B.....	23	Abortion	150 cc.	0	0	
3	J. M.....	34	Abortion	350 cc.	0	0	
4	E. S.....	28	Abortion	100 cc.	0	0	
5	M. S.....	24	Abortion	750 cc.	0	0	
6	H.....		Puerpural sepsis	700 cc.	0	0	
7	L. R.....	4	Otitis media	230 cc.	0	0	
8	H. G.....	14	Infected toe	290 cc.	0	0	
9	S. C.....	19	Respiratory infection	158 cc.	0	0	
10	V. C.....	8	Mastoiditis; lateral sinus; thrombosis	200 cc.	4 of 200 cc. each	0	Mastoidectomy; removal of thrombus
11	M. W....	7	Lateral sinus; thrombosis; mastoiditis	150 cc. horse 150 cc. bovine	6 of 150 cc. each	0	Mastoidectomy; removal of thrombus 75 cc. of Pregel's iodine
12	M. D.....	36	Laceration forehead, orbital cellulitis				
13	M. N	31	Cellulitis of leg				
14	B. H.....	23	Cellulitis of leg	220 cc. bovine			
15	C. D.....	26	Abortion	460 cc.	0	0	

action either on primary or secondary foci. Such foci, if demonstrable or accessible, must be treated surgically. Extreme care, however, must be exercised in handling any particular focus or organ, especially the infected

uterus. We accept the dictum that the less this organ is manipulated, the greater the chance for recovery. In instances where the uterus contains pieces of infected placenta, or the entire product of conception, without removal of this primary source of infection, nothing will be accomplished by serum treatment. Likewise, if infected thrombi are present in the blood-vessels or on the heart valves, even successful sterilization of the blood-stream will avail nothing; the blood-stream will become reinfected in a short time from these points. Furthermore, even in the absence of secondary foci or thrombi, serum treatment will fail if the administration is delayed until extensive degeneration of the parenchymatous organs has taken place. Systolic pressure usually is an excellent index; if it falls below 100 it usually means marked toxic changes in the myocardium or dilatation of the heart.

The best results with antistreptococcus serum are obtained when the serum is administered early and in sufficient quantities intravenously before the development of secondary foci or thrombi and marked degeneration of the parenchymatous organs. In this series we have employed from 100 to 850 cubic centimetres in each case. As a rule, if 200 cubic centimetres of serum produce no definite improvement in the general condition of the patient or decrease in the number of bacteria in the blood-stream, further administration will be useless.

Method of administration.—Administration of serum, especially intravenously, should be done with extreme caution. We must remember that we are introducing into the circulation a foreign protein, horse or bovine serum, and that many individuals are naturally sensitive or have become sensitized to different proteins, particularly to horse serum. One should question not only the patient, but also investigate the family history about asthma, hay fever, rose cold, urticaria, angioneurotic œdema and sensitiveness to foods or animals, especially the horse.

We have two cases, both sons of surgeons, who gave at first a negative personal and family history. When the introdermal tests turned out to be positive, both fathers announced that in the years gone by one was subject to hay fever and the other to rose cold. Both sons were truly allergic to horse serum. If this be the case, administration of horse serum, especially intravenously, very likely would kill the patient in anaphylactic shock. Desensitization of such individuals is, as a rule, impossible. Sensitiveness to bovine serum is less common, but the safety of its use should not be taken for granted without the proper tests.

The patient should be questioned about previous injections of serums, such as diphtheria or tetanus antitoxin or other sera, including diphtheria toxin-antitoxin mixture for immunizing purposes. Even in cases with a negative history, the intradermal test should be done. These patients, as a rule, can be desensitized satisfactorily by giving subcutaneous injections of serum at two-hour intervals starting with 0.01 cubic centimetre and then increasing to 0.1, 0.2, 0.5, 1.0, 2.0, and 5 cubic centimetres. After this it is safest to

give five and ten cubic centimetres intramuscularly at the same interval, before proceeding with intravenous administration.

To carry out the skin test, inject *intradermally* about 0.1 cubic centimetre of the serum to be used or until a wheal about seven or eight milligrams in diameter is produced. If the test is positive, in ten or fifteen minutes the wheal will increase considerably in size and will be surrounded by a fairly wide zone of hyperæmia; if negative, the wheal will only slightly increase in size, and there will be only a line of hyperæmia. In positive cases desensitization should be carried out. If the test is negative, one may proceed with the intravenous injection of the serum. We must remember, however, that negative history and intradermal test are not absolute indication of absence of protein sensitization. Hence, the first dose of serum intravenously should be given with extreme care. Dilute the serum with physiological salt solution about 1:20 and introduce it very slowly by means of intravenous apparatus so that the patient does not receive more than twenty cubic centimetres of the diluted serum in the first ten minutes. Before the beginning of the intravenous injection have ready for use in a syringe adrenalin and atropine sulphate. Should anaphylactic shock develop, these drugs will be needed immediately. Fortunately, we have experienced no serious difficulties in this series. We have had to stop the administration of the serum and administer adrenalin and atropine only in two cases. After the lapse of ten minutes, the rest of the serum may be added to the reservoir and administered quite rapidly. At subsequent injections the serum can be administered more rapidly, either directly from the original container or with a syringe. Needless to say, the serum injected should be at body temperature. We usually give twenty-five or fifty cubic centimetres at the first injection, and fifty or 100 cubic centimetres at a later time. It is better to give two or three smaller injections in twenty-four hours than one large dose. Blood cultures should be taken every day until they become negative. One should plan to administer all the serum intended to give in six days, since after that time the patient may become sensitized to the serum and administration after the lapse of that period may lead to disastrous results. Should the patient be sensitive to horse serum or should the injections be prolonged beyond the six-day period, one may use the antistreptococcic bovine serum, which, fortunately, has been available in the last few years.

CONCLUSIONS

1. It has been shown in the analysis of forty-three cases of hæmolytic streptococcus blood-stream infections that polyvalent antistreptococcic serum is of a decided value in the treatment of these cases.

2. Twenty-one cases received no serum, four cases received insufficient amounts and in late stages. Five cases, or 21 per cent., recovered. Nineteen cases, or 79 per cent., died.

3. Nineteen cases were treated under conditions which were satisfactory

for the test of the value of the serum. Four cases, or 21 per cent., died and fifteen cases, or 79 per cent., recovered.

4. The serum had no effect on either primary or secondary foci and infected thrombi in the circulation.

5. Differentiation has been made between "shower" and "massive" invasion of the blood-stream by bacteria.

6. Precautions and a method of administration of serum have been outlined.

7. The importance of surgical treatment of primary and secondary foci has been emphasized.

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STUDIES ON THE ACTIVITY OF THE LUMBAR SYMPATHETIC NERVOUS SYSTEM

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The investigations of Hunter and Royle[1] on the sympathetic nervous system have opened a relatively new field for surgical exploration. Pioneers have prospected on the influence of the lumbar sympathetics in such conditions as spastic paralysis; Raynaud's disease; thrombo-angiitis obliterans; Hirschsprung's disease; arthritis deformans; trophic ulcerations, *etc.* These patients have been selected as carefully as possible from the clinical symptoms of the disease.

An attempt had also been made to refine the diagnosis in the vascular disease group so that patients with marked vasospasm could be separated from the organic obliterative types without spasm. Brown[2] suggested the intravenous injection of a foreign protein (typhoid vaccine) in sufficient doses to produce a systemic rise in temperature of from 1 to 2° C. The changes in the surface temperature of the involved part compared to the general systemic reaction give an index of the vasodilatation and increased blood flow. In Raynaud's disease the surface temperature changes are striking; in thrombo-angiitis obliterans the changes are variable, depending on how extensive the spastic element enters the picture. This vasomotor reaction has proved quite useful as an indication of the probable value of an operative attack on the sympathetic nervous system. It is only fair to state, however, that the patients often are extremely uncomfortable following this test. There is frequently a violent chill with a fear of impending death; preëxisting pain may increase and various body aches may appear; the discomfort may become so marked that morphine is required; and the whole reaction may extend over a considerable time. It has been our experience that patients often refuse a second injection offered as treatment. Allen and Smithwick,[3] furthermore, have noted the development of thrombosis during the early stage of the reaction in arteriosclerotic individuals so that amputation was necessary in two instances.

The present studies represent an attempt to gain information in the vascular diseases with less discomfort and less disturbance to the endothelium of the vessels. Also the method developed affords information concerning the functional state of the innervation in other systems supplied by the lumbar sympathetic outflow.

Hirschsprung's disease.—Over-activity of the sympathetic nervous system has been assumed to be responsible for the conditions in which operative

intervention on this system is advocated. In Hirschsprung's disease, this is based on the success of this operation first reported by Wade and Royle.[4] No very definite information is available as to the exact mechanism of this stimulation. Judd and Adson[5] state that "it is impossible to determine whether this hyperactivity is due to an irritating lesion of the ganglia, of the post-ganglionic or the pre-ganglionic fibres, or is of central origin." They were of the opinion that it was probably of central origin.

In dealing with a case of this kind we thought that it would be desirable to get more information, if possible, both concerning the mechanism involved

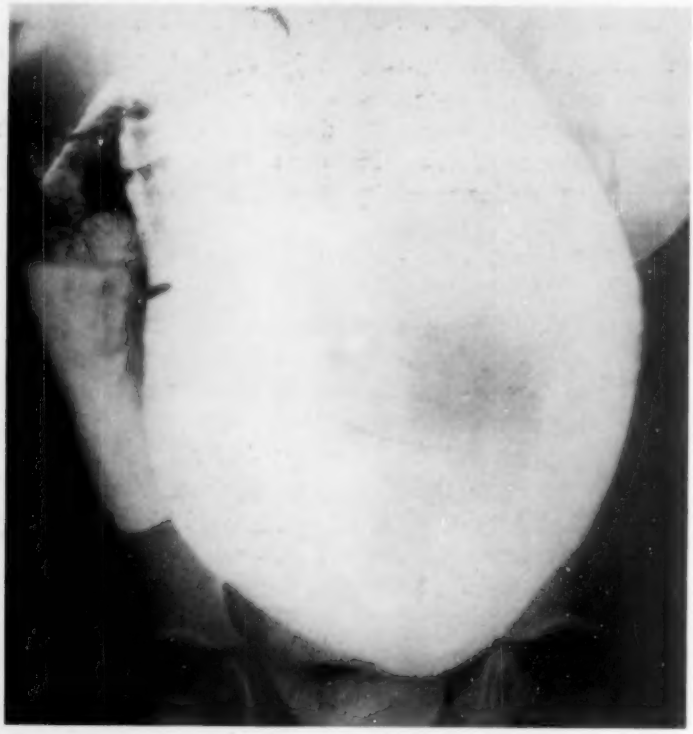

FIG. 1.—Typical Hirschsprung's disease. Barium enema on admission. (Case I.)

and, as a practical point, for prognosis. All central impulses, including autonomic, can be blocked off chemically by the use of spinal anæsthesia. This offers a method for showing whether the sympathetic over-activity is of central origin; and if it is, it gives a test by which an accurate estimate may be of the value of removing this stimulation.

CASE NO. 23255.—A seven-year-old boy was admitted to the Strong Memorial Hospital on September 7, 1929. He presented a typical example of congenital idiopathic dilatation of the colon. This was diagnosed from the characteristic history, the examination, and the röntgenogram (Fig. 1). All therapeutic attempts to produce normal evacuation of the bowels had been failures. He was often completely constipated for two or two and one-half weeks and at the end of such a period there might be nausea and vomiting of very foul material. He had never had a spontaneous movement in his

life. Repeated fluoroscopic examinations failed to reveal evidence of peristaltic action, and the whole colon appeared atonic. Four quarts of barium were introduced per rectum with no discomfort or painful sensations. He was able to expel only one quart of this mixture as his maximum effort (Fig. 2). Spinal anæsthesia was given. He

FIG. 2.—Maximum expulsion before spinal anæsthesia.

FIG. 3.—Twenty minutes after spinal anæsthesia. Ascending and transverse colon nearly empty. Sigmoid decidedly narrowed.

became extremely restless, complaining of what he called "itching in the stomach." This was followed by the expulsion of gas and barium. Peristaltic rushes came at irregular intervals of two or three minutes, lasting from thirty to sixty seconds. A bed pan was filled in the next fifteen minutes without difficulty. By this time the whole right colon had been practically emptied and the sigmoid was much narrowed (Fig. 3). A röntgenogram taken three and one-half hours after the spinal anæsthesia showed quite marked emptying of the large bowel (Fig. 4). Spinal anæsthesia had transformed the tremendous atonic bowel into one which had excellent expulsive power with peristaltic rushes. A bilateral lumbar sympathectomy was done on October 8, 1929. He had the first spontaneous bowel movement in his life on October 19, 1929. The bowel has been evacuated without medication, one to three times daily since this time. He had gained 1.6 kilos (three and one-half pounds) by January 10, 1930. He was having two regular formed stools daily. It required only two quarts of barium solution to completely fill the colon. Even this amount caused tremendous discomfort and desire to expel it. The haustral markings were sharply defined. Expulsion of the barium was complete with no trace whatsoever in any portion of the colon (Figs. 5 and 6).

FIG. 4.—Three and one-half hours after spinal anæsthesia.

Thus, in this instance, it was possible to demonstrate that the over-activity of the sympathetic was under central influence; and an accurate prognosis could be made as to the probable effect of lumbar sympathectomy.

We were sufficiently encouraged by this experience to make use of spinal anæsthesia as a test in our next case of Hirschsprung's disease.

Case No. 32554.—A five-year-old boy was admitted to the Strong Memorial Hospital on February 19, 1930. Here again we were dealing with a typical example of the disease. The history, the physical examination and the röntgenogram were quite characteristic. He frequently went for nine days without a movement. Ordinary cathartics and enemas were useless but some form of "patent tea" had been used with enemas successfully. On only two occasions during his life had there been a desire to go to stool; and there had never been a spontaneous evacuation. The large bowel held three and a quarter quarts of barium mixture, as the röntgenologist's report states, "an amount sufficient to fill the colons of two normal adults." There was no complaint and no evidence of peristalsis. The patient was asked to expel all that he could. After fifteen minutes of effort he had passed nothing. Spinal anæsthesia was then administered. Approximately ten minutes later sudden peristaltic rushes occurred with the expulsion of most of the colon's contents. A moderate amount of barium remained in the descending colon. The patient scratched at his abdomen and complained of "itching." The spinal anæsthesia had produced definite changes in the tone of the large bowel, which showed lessening in its dilatation, and evacuation of at least three-fourths

Fig. 5.—Discomfort caused by half the amount of barium given without sensation before operation.

Fig. 6.—Complete voluntary expulsion of enema.

of its contents. We believe that this is evidence that lumbar sympathectomy will be effective in this case. The patient will probably be operated upon in the near future.

This experience with clinical cases of Hirschsprung's disease pointed to the desirability of further testing the results of spinal anæsthesia on the large bowel in experimental animals. Cats were selected as the animals of choice because previous investigators have commented on the lack of movements in the colon of the cat when the abdomen was open. Light ether anæsthesia was employed and a laparotomy performed. The colon remained inert and motionless in all cases examined except one that showed a little feeble peristalsis which quickly ceased entirely. This was in decided contrast to the activity of the small bowel. Even when the large bowel was distended by fecal material or artificially by fluid introduced through the ileo-colic junction, it remained inert and there was no evacuation. A local rhythmic contraction could be induced by a mechanical stimulus such as pinching or handling but no coördinated peristaltic action was observed. Spinal anæsthesia was then employed. In five to ten minutes, the large bowel

became very active. Contractions occurred in both the longitudinal and circular fibres with a resultant shortening of the whole segment and deep peristaltic waves. Peristalsis took place over the whole upper colon, contractions being rhythmic, and both ascending and descending in nature. There was a transformation from a toneless, flabby bowel to a moving, tense segment. No actual emptying of the colon took place under ordinary circumstances when it was not very full. But if the colon had been distended artificially (to simulate the conditions in Hirschsprung's disease) emptying was marked and rapid. This response was typical and it was observed in every animal studied. Also it was impossible to distend the colon with fluid when under the influence of spinal anæsthesia.

Removal of the central influences on both the sympathetic and parasympathetic terminals causes the intrinsic nervous mechanism of the bowel to function without inhibition. This result may be accomplished at operation by destroying the sympathetic nerve supply either by ramisection, by removing the lumbar ganglia, or by dividing the post-ganglionic fibres. Whether the activity of the bowel after such an operation is due to the function of the intrinsic nerve supply alone or is augmented by the parasympathetic tone will require further investigation. It is reasonable to suppose, however, that all central influences are abolished by the spinal anæsthesia block. This study has been fully reported elsewhere (Scott and Morton[6]).

Vascular diseases.—The response of the vessels of the lower extremities to spinal anæsthesia can be easily followed by measuring the surface temperatures.* The latter are determined after the feet have been exposed for some time at a temperature of about 22° to 23°, so that a base line can be obtained. Spinal anæsthesia is then given and the surface temperatures are recorded at intervals. We have found by this method that individuals with clinically normal blood-vessels may show one of two types of response. Most people literally show "cold feet" by actual temperature measurements, when they come to the operating room. The temperatures may be only slightly above 22° C. When spinal anæsthesia is given to them there is usually a sharp increase in the surface temperature of the feet until the rise is well over 30° C., at times to 35° C. This is the more common response. On the other hand, when there is a fever, or in the presence of a debilitating disease, the reaction may be only a very slight rise or even a prolonged slow fall. In these individuals the surface temperatures of the feet are over 30° C. before the spinal anæsthesia is given. It is an indication that the vasodilatation is already acting at its maximum; or at least that there is no sympathetic vasoconstriction at the time of the examination. Patients with organic vascular disease such as endarteritis obliterans, in which vasospasm has no major part, show no change or a fall in surface temperature after

* The surface temperature readings were made with a simplified compact instrument of the thermocouple type, developed under our direction by the Taylor Instrument Company, of Rochester, New York. (For description of this instrument see J.A.M.A., 1930, 94, 1987.)

spinal anæsthesia. Patients in whom there is organic vascular disease with an element of vasospasm as in thrombo-angiitis obliterans, show a moderate to marked rise in surface temperatures following spinal anæsthesia. After lumbar sympathectomy the surface temperatures of the feet usually record at a high level. Spinal anæsthesia has no effect on such surface temperatures unless some fibres have been overlooked. In the latter case there may be a feeble response. When a unilateral lumbar sympathectomy has been done, spinal anæsthesia may show a considerable difference between the sides, provided the unoperated side has some spastic vascular disease. When no disturbance of the vascular system is present, the difference between the two sides may be slight under ordinary conditions. It is usually possible, how-

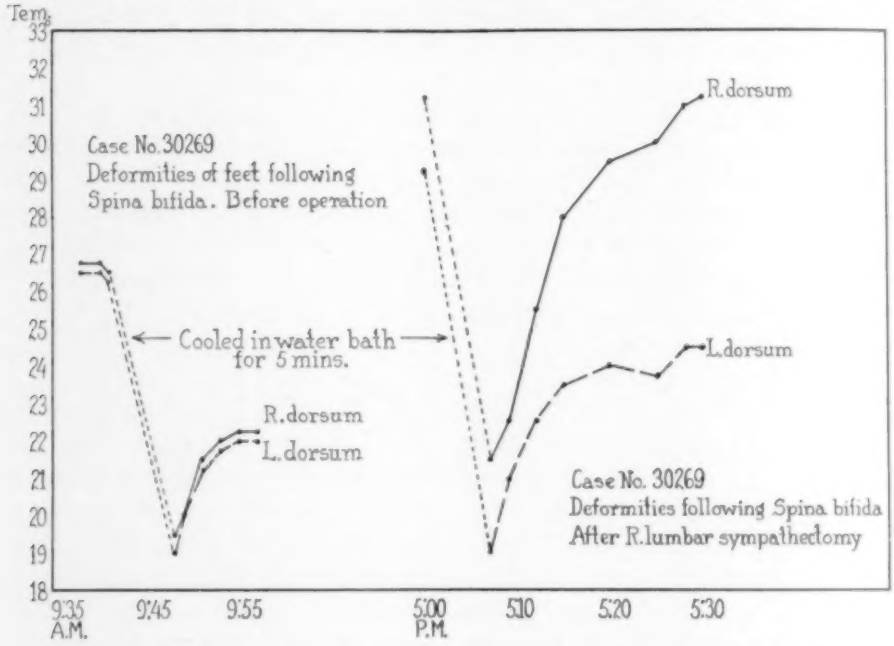

FIG. 7.—Test for vasomotor activity before and after sympathectomy in spina bifida.

ever, to bring out the contrast between the sympathectomized and the non-sympathectomized limbs. By artificially cooling both sides in a cold bath, the surface temperatures may be reduced to a low level. On being allowed to recover, the operated side responds with a quick sharp rise to its maximum. The unoperated side also reacts but the curve after the first two or three minutes is slow and prolonged. It requires a considerably longer time for the unoperated limb to reach its previous surface temperature (Fig. 7).

We believe that low spinal anæsthesia offers a safe test for the lumbar sympathetic effect on the vessels of the lower extremities. We regard it as a quicker, safer, more certain and more selective index of the probable effect of lumbar sympathectomy than the foreign protein reactions. The detailed study of these vasomotor reactions with charts has been reported elsewhere. The normal vasodilatation level, the occlusion index, and the vasoconstrictor

gradient have been defined and their significance discussed (Morton and Scott[7]).

Painful states of possible sympathetic origin.—Patients with painful amputation stumps are notoriously difficult to treat with uniform success. This is partly due to inadequately determining the exact cause of the pain. But even when a careful analysis has been made and the pain seems localized to the nerve trunk, to local vasomotor influence, or to the sympathetic nervous system, a small percentage of failures remains after any type of treatment. A recent experience with a case of this kind has convinced us that some of these patients have a true hysteria imposed on the local condition. Our patient had evidence pointing to involvement of the nerve trunk and possibly to a vasomotor neurosis. Operation for the correction of these conditions resulted in only temporary benefit. The question of a further operation, this time on the lumbar sympathetic trunk, was next considered but it was decided first to apply spinal anæsthesia as a test. This revealed that even complete section of the spinal cord would not have removed the consciousness of the painful impressions projected to the amputated limb. Now that the local conditions have been corrected, it seems that psychotherapy has a better chance for success in this case than any other treatment. This psychoneurotic type of patient may be responsible for the failures reported in the treatment of these conditions.[8] A brief summary of this case is presented here.

Case No. 31637.—A fifty-year-old man was admitted to the Strong Memorial Hospital for the first time on February 10, 1930. He had had a crushing injury to the left leg on May 9, 1929, and when gangrene resulted an amputation had been done. He had begun to complain of pains across the instep and under the toes of the amputated foot shortly after the operation. The pains had been steady and continuous, not boring nor burning in character. Abscesses had formed in the stump. Drainage and reamputation had been done elsewhere. In spite of this he still felt the pains projected to the amputated foot. When first seen by us he had a small residual abscess in the stump, an adherent scar, a sensitive sharp bone end, and a painful sciatic nerve end-bulb. He was a nervous patient. His right foot was cold, blue and moist suggesting a sympathetic nerve disturbance. After careful study, a reamputation was done with resection of the nerve bulb, alcohol injection of the sciatic, and periarterial sympathectomy of the femoral artery. The patient was almost completely relieved of his painful sensations in the phantom limb till twelve days after operation. At that time he began to suffer with his foot again and soon complained of it as bitterly as before operation. Lumbar sympathectomy was at this time considered as a possible operation for relief but it was decided to test the effect of spinal anæsthesia on his pain. This was done on March 6, 1930. Although he obtained motor paralysis of the right lower limb and left thigh and complete sensory anæsthesia to about one inch below the nipple line, he still complained of pain in the left foot as severe as before the spinal anæsthesia. The diagnosis of psychoneurosis was made and he was referred to a psychiatrist for treatment.

Traumatic neurosis, arthritis, ulcer.—There is a heterogeneous group of conditions for which operations on the sympathetic system have been reported as sometimes producing brilliant results. This group includes such lesions as trophic ulcerations; traumatic œdemas; traumatic arthritis; arthritis

deformans; *etc.* So far, we have had too few cases of this group to allow us to make very definite statements and up to now have had to select such patients for operation empirically. We are confident, however, that it will be possible to develop selective functional tests so that some of these patients may be chosen for operation with assurance that success will follow. It has been assumed that there is a derangement of the normal vascular supply in the production or in the maintenance of these states. A sufficient number of such cases have been reported from several clinics to lend weight in certain of these cases to the hypothesis that there is a sympathetic over-activity. We have used spinal anæsthesia in this group, recognizing that the activity tested is merely vasomotor. Such evidence is at best indirect and not a direct test of the function in the system involved as was the case with the large bowel and the vascular diseases. In several of these cases there was definite clinical evidence of sympathetic over-activity manifested by coldness, cyanosis and increased perspiration in the involved extremity. Spinal anæsthesia completely abolished the clinical and temperature differences in the two legs. Still, we are by no means certain that the underlying condition in each case will be benefited by operation, as the reactions are in no sense selective for the functions of the joints, the lymphatics, or the general tissues of the extremity. So far as we can determine, they tell us about only the vasomotor activity. This factor can be controlled by operation. It is often quite difficult to determine what course of treatment should be chosen even when the sympathetic nervous system can be implicated. In a case of traumatic arthritis, for example, lumbar sympathectomy was seriously considered for some time when the symptoms were pronounced and improvement did not take place on conservative treatment. By patient waiting, however, all the trouble disappeared. This would have been a splendid result if lumbar sympathectomy had been done.

Case No. 23456.—A fifty-seven-year-old man was admitted to the Strong Memorial Hospital on April 9, 1929. He entered because of a painful swollen right foot. He had noticed pain in his right foot three months before but it had not caused sufficient trouble to require medical attention. After driving across the continent to California, the pain increased but he still continued about his activities. Two weeks before admission the right foot became swollen. Examination was normal except for the right foot which was œdematous over the dorsum and toes. There was no localized tenderness. Active dorsiflexion was the most uncomfortable movement but there was very little pain either on active or passive motion. He had no fever and no foci of infection were demonstrated. Röntgenograms showed indistinct joint spaces about the small bones of the mid-foot. There was marked washing out of the calcium from the bones and some of the changes were thought to be destructive. He was discharged on April 11, 1929, with a diagnosis of traumatic arthritis. He was restricted in his activities, protected his foot as much as possible and had physiotherapy. There was a progressive increase in calcium loss from the bones as revealed by X-rays over the next six months. His condition was regarded by various consultants as tuberculosis, sarcoma, or some disorder on a neurological basis. Amputation was advised by a leading surgeon but was wisely refused by the patient and his physician. Lumbar sympathectomy was seriously considered but a further period of conservative treatment was recommended first. Improvement began about two months later and progress was steady. Calcium was

redeposited in the bones which resumed their normal röntgenographic outline. The joints showed no destruction. Function returned slowly to normal. This case is presented through the courtesy of Dr. T. B. Jones. It is our impression that sympathectomy would have hastened the return to normal. This case shows the possibilities of conservative treatment. The age of the patient and his economic status as well as the danger of permanent functional damage should be considered by the surgeon in deciding upon treatment.

In a case of traumatic œdema of the leg with decided clinical sympathetic symptoms, spinal anæsthesia abolished the coldness and excessive moisture of both feet. The local fibrous tumor in the region of the tendo Achillis was removed. We hope that this will bring about a clinical cure but the question of lumbar sympathectomy is naturally still unsettled.

Case No. 32949.—A thirty-two-year-old man was admitted to the Strong Memorial Hospital on March 13, 1930. He was knocked down by a truck on September 17, 1929, and the rear wheel injured his right heel. There was laceration of the skin and exposure of the deeper structures with a painful bluish swelling of the whole foot. Röntgenograms showed no fractures. He was treated by physiotherapy but was unable to bear weight on the foot till late in January, 1930. One month later he could walk unsupported but there was persistent painful swelling about the ankle which caused great annoyance. On examination he showed a firm, slightly painful swelling alongside the medial edge of the Achilles tendon. Both feet were cold and moist but the coldness extended higher up the leg on the injured side. The veins of the right side were quite prominent and there were two dark brown patches over the right tibia, the residuum of an ecchymotic area. There was hyperæsthesia over the right ankle and heel. All movements of the foot were restricted, and the patient walked with a limp, bearing his weight on the outer side of the right foot and the toes but scarcely touching the heel to the ground. The right foot would become blue, swollen and œdematous after he had been on his feet for a short time. A mass of scar tissue was dissected free from the tendo Achillis on March 15, 1930. Spinal anæsthesia was used and both feet showed a striking rise in surface temperature becoming warm and dry. The condition will be carefully followed and unless improvement takes place, lumbar sympathectomy may be recommended. This case is presented through the courstesy of Dr. S. J. Stabins.

We are working our way cautiously with cases of chronic non-specific polyarthritis which show any clinical suggestion of vasomotor over-activity. We feel that all such cases at present are experimental studies and sympathectomy has been done only after every other therapy has failed. The patient is given to understand that the attempt is in the nature of an experiment as we have no specific test to be applied beforehand. In four cases of such arthritis, three of them have shown a well-marked vasoconstrictor activity which has been obliterated by spinal anæsthesia. We have no way of knowing at present whether this sympathetic activity is more continuous than it is in normal individuals.

It seems probable that there will be a field for lumbar sympathectomy in cases of spina bifida with sensory impairment in the lower extremities. In these cases there is undoubtedly disturbance on the vasomotor side. We have not desired to change the subarachnoid pressure relationships with spinal anæsthesia in them. We have had two experiences, however, which convince us that the removal of the lumbar sympathetic chain is valuable. In one case this was done to cure a trophic ulcer, and in the other to provide the best possible nutrition as a prophylaxis against ulceration. One of these

cases with unilateral operation gave us an opportunity to compare the two limbs. The recovery of the surface temperature after cooling by a cold bath was much more rapid on the sympathetomized side. (See Fig. 7.) These case reports are briefly presented here.

Case No. 6326.—A twenty-year-old man was admitted to the Strong Memorial Hospital for the fifth time on January 28, 1930. His previous admissions were for operations to correct the deformities of bilateral talipes equino-varus resulting from a large, untreated spina bifida. There was also a cystitis due to internal sphincter paralysis; and a diverticulum of the penile portion of the urethra. There was loss of pain sensation alone in the distribution of the sacral third, fourth and fifth nerves. The present admission was subsequent to the development of an infected calloused area on the sole of the left foot. There was a hemolytic streptococcus infection over the dorsum of the foot which required incision and drainage. Inasmuch as the ulceration was present in an area of impaired sensation and had not improved for six months, it was looked upon as a trophic disturbance. Accordingly, on February 12, 1930, a left lumbar sympathectomy was done. Although there was evidence of infection and bone destruction in the distal end of the first phalanx of the fifth toe, the sympathectomy definitely increased the peripheral circulation and the swelling rapidly subsided. The ulcer was completely healed by March 14, 1930.

Case No. 30269.—A four-year-old boy was admitted to the Strong Memorial Hospital on December 8, 1929. The child had a myelomeningocele which had been operated upon shortly after birth. He entered the hospital because of marked deformities of the feet. These consisted in an equino-varus on the right with a large reddened bursal development over the dorsum of the foot from faulty weight-bearing; and an equinus on the left. There was also a loss of painful sensation in the soles of the feet; and a constant overflow from the bladder. The feet when exposed were cold, clammy and blue. It was evident that attempts to hold the feet in corrected positions would be quite likely to result in ulcerations in these areas of impaired sensation. It was decided that since lumbar sympathectomy was the best treatment for trophic ulcerations on the feet, it should, therefore, be the best prophylaxis. As a preventive measure, right lumbar ganglionectomy was done on December 18, 1929, at the request of the orthopædic surgeon. There was a striking clinical improvement in the circulation, the foot on the operated side becoming pink, dry, and so much warmer than the opposite foot that it was obvious on palpation. Surface temperature readings showed the difference to be 2° C. on the dorsum of the foot. The orthopædic correction is now being carried out.

Discussion.—The advances in the surgery of the sympathetic nervous system, to date, have been made in an empirical fashion, the surgeon hoping that the operation he does will be of benefit to the patient. As yet, selective tests for its participation in the various clinical syndromes have been lacking. The nearest previous approach to a test for sympathetic over-activity is the intravenous injection of typhoid vaccine for its effect on the vascular system. In an endeavor to obtain a more selective reaction, it seemed to us that temporary paralysis of the sympathetic nerves was rational. By using spinal anæsthesia, we were able to study the large bowel and the peripheral vascular system of the lower extremities freed from sympathetic activity. It is thus possible to demonstrate whether operative interruption will be beneficial; and also how effective it will be. We are confident that the effect of spinal anæsthesia will yield this information both in Hirschsprung's disease and in vascular diseases of the lower extremity. Probably further simplification of

this method can be achieved. The effects of general anæsthetics on the peripheral temperatures have already been recorded by several investigators.[9, 10] There is a rise in the cutaneous surface temperature following ether and nitrous oxide anæsthesia. It is uncertain just how general anæsthetics produce their peripheral effects and consequently we have not reported them in this study, as we have desired first to establish the basic response to a known paralysis of the sympathetic innervation. We are now studying the availability of nitrous-oxide oxygen anæsthesia as a simplified procedure to measure sympathetic vasoconstriction in the extremities. Also, it is desirable to develop new reactions as selective tests in other diseases for which the sympathetic system is assumed to have a major rôle. Such a pre-operative determination should be the aim of all those who are doing this type of surgery.

CONCLUSIONS

1. An important step in advancing the surgery of the sympathetic nervous system is the development of methods to accurately predetermine the degree of its functional involvement in each case.

2. Such tests will permit the proper selection of cases and will indicate the probable outcome following operation in any individual case.

3. Spinal anæsthesia offers such a diagnostic test to estimate the participation of the lumbar sympathetic nervous system.

4. It is possible by this means to show temporarily over-activity of central origin.

5. The sympathetic element thus shown may, therefore, be permanently controlled by operation.

6. A functional test for Hirschsprung's disease is the effect of spinal anæsthesia on the motility and expulsive power of the large bowel as determined with a barium enema.

7. A functional test for vascular diseases of the lower extremity is the change in the surface temperatures of the feet following spinal anæsthesia. It is thus possible to demonstrate the proportionate amounts of organic obliteration and vasospasm. It is a safer, surer, quicker, and more selective test than the reaction to foreign protein.

8. No specific functional tests have been evolved for trophic ulcerations, traumatic arthritis and œdemas, non-specific polyarthritis and states of nervous origin as poliomyelitis, *etc.* This group requires further study. Vasoconstriction can be demonstrated in these conditions but its significance is not clear.

9. Spinal anæsthesia may be of great value in the differentiation of true pain of sympathetic origin from psychoneurosis.

10. Lumbar sympathetic ganglionectomy provides improved circulatory conditions in deformities of the lower extremities consequent on neurological lesions, as in cases of club foot due to spina bifida. It should be given consideration in the prophylaxis as well as in the treatment of trophic ulcerations.

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RECENT ADVANCES IN THE TREATMENT OF CIRCULATORY DISTURBANCES OF THE EXTREMITIES

RESULTS OBTAINED IN THE PERIPHERAL CIRCULATORY CLINIC OF THE MASSACHUSETTS GENERAL HOSPITAL

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In November, 1928, a special assignment was granted to a small group from the surgical staff at the Massachusetts General Hospital to study and treat circulatory diseases of the extremities. A special clinic was established in the out-patient department where ambulatory and follow-up cases are seen and treated each Saturday morning. Patients requiring hospital care are visited by the entire group once each week and their treatment supervised. The management of diabetics coming under this assignment has been admirably adjusted to the needs of the hospital by Dr. Leland S. McKittrick, of our group, and Dr. Roy Wheeler, of the Medical Service. Drs. J. C. White, R. H. Smithwick, and H. H. Faxon have worked out many of the details and carried out valuable research in this field. The advice of Dr. George S. Van Gorder, of the Orthopedic Service, concerning the adjustments of arch supports and shoes, has been of great value. The assistance of Dr. J. F. Kelly, in caring for the calluses and nails of these patients, has been helpful.

It was primarily our intention to devote the greater part of our effort to the study and care of cases with peripheral arterial disturbances and it is with these that we will deal chiefly in this résumé. It has been necessary, however, to devote a great deal of our time to the management of varicose veins, inasmuch as the injection method of treatment has recently created such a tremendous demand from these patients.

From December 1, 1928, to May 1, 1930, 763 new cases have come to the clinic with a total of 3650 visits. Five hundred and sixty-nine were cases of varicose veins; the remaining 194 patients suffered from some other form of circulatory disturbance. During this period of sixteen months we have treated 149 patients in the house with an average of thirty-two and four-fifths hospital days. With a review of the work to date and our previous experience, we wish to present our conception of the proper management of such cases as it stands today.

Varicose veins.—A detailed report of our experience with the injection method of treatment in these cases will shortly be made by one of the clinic.[1] Here suffice it to say that in dealing with a large number of patients, seen usually once a week, the repeated injection at intervals has been more satisfactory than the multiple massive injections advocated by some. The solution found best suited to our needs is quinine and urethane. On the whole, the results have been amazingly successful, and if the internal saph-

enous and other large superficial radicals in the thigh are sclerosed as well as those below the knee, we have reason to believe that the majority of cases will remain relieved. We have already seen some recurrences in patients whose treatment was not carried above the knee. We have had a few excessive reactions from small doses of solution, in a few instances, sufficient to confine the patient to bed for a short period of time. We have also had a few troublesome sloughs when the solution was given so that the fluid escaped or was inadvertantly injected into the surrounding tissue. In one case one cubic centimetre of quinine and urethane given as a second injection low in the leg produced a thrombosis of the entire saphenous with symptoms and signs of an acute phlebitis. This patient was confined to bed for ten weeks during which period she had three typical pulmonary emboli.

LESIONS OF THE EXTREMITIES DUE TO ARTERIAL INTERFERENCE

General considerations.—Etiologically, most circulatory disorders of the extremities remain a mystery. The pathology, however, is quite well understood. The majority of cases that present themselves for treatment have many characteristics in common, regardless of their age, sex, nationality or type of arterial obliteration—such symptoms as pain, intermittent claudication, insomnia and a lowered tolerance for cold, may be complained of by all. Extremities will blanch on elevation and become cyanotic on dependency. The surface temperature is lowered to a degree measureable by touch, and the peripheral arteries are prone to pulsate feebly or not at all. Often there is a beginning ulceration, trophic disturbance, or gangrene. Due to the upright position of man and the consequent greater strain on the circulation of the feet and legs, the majority of these disorders involve the lower extremities. Many patients diagnose their own condition as flat feet, and seek relief through arch supports and special shoes. That these disorders should have symptoms and signs in common is easily understood when one considers that there is in all of them a deficient blood supply. Although this makes the diagnosis difficult and in border-line cases a cause for argument, it does help in the general treatment of such cases.

Classification.—We believe that simplicity is essential, and therefore classify these diseases into two main groups: first, those with mechanical arterial obliteration; and secondly, those dependent upon vasomotor imbalance. Under the former we have true arteriosclerosis of the senile type and that associated with the comparatively younger diabetic, also, the young and middle-aged individual with progressive obliteration without calcification, the majority of whom have thrombo-angiitis obliterans (Buerger's disease), and a few cases in this group with disease of the middle coat of the artery belonging to the type of arteriosclerosis described by Mönckeberg. In the second, or vasomotor, group there is a great variation as to the extent of the process, from a mild form of multiple phase color change noticeable only on exposure to cold, to a progressive trophic disturbance leading to gangrene of the tips of digits and a more generalized scleroderma. The

former may be referred to as phasic and the latter as constant, the term Raynaud's disease being loosely applied to all cases of vasomotor imbalance. It is important to note that in many cases of obliterative arterial disease that a definite but variable vasomotor influence may be superimposed.

Examination and history of the patient.—It is important to take into consideration the duration of symptoms; the extent and period of disability; the type of work; injury or previous inflammatory processes such as phlebitis; the amount of generalized arteriosclerosis; stability of the nervous system and habits—any or all of these may throw considerable light on the diagnosis and prognosis. During the examination it is best to have all the extremities fully exposed. Although only one may be sufficiently troublesome for complaint, the other extremities may be involved to a lesser degree; at any rate, a better estimation as to the extent of the process can be ascertained by a comparison of the two sides. Inspection may reveal swelling, cyanosis, rubor or pallor. Touch gives an idea as to surface temperature. Palpation of the peripheral vessels is most important. The dorsalis pedis, posterior tibial and popliteal arteries should be taken into consideration as to the approximate volume of blood flow and the texture of the vessels. If the popliteal is absent, it is well to follow the femoral from Scarpa's triangle down as far as possible through Hunter's canal. The legs should then be elevated to forty-five degrees and the rapidity of blanching observed. Although a comparatively normal foot will become more pale on elevation, the cadaveric hue of the extremity in cases of arterial insufficiency in this position is unmistakable. A recent article by Samuels[2] suggests that in making this test the patient be asked to flex and extend his toes, as this brings out the pallor more strikingly as the motion hastens the blood out of the foot. Following this, the extremities should be lowered and the amount of time necessary to bring about rubor and cyanosis noted. The extremities that become cadaveric in less than two minutes of elevation or become cyanotic on dependency in a like time are deficient in circulation, regardless of the pulsation in the peripheral arteries. More detailed methods of examination can be done in the hospital, such as actual measurement of the surface temperature by the thermo-couple; estimation of the blood flow with the Pachon oscillometer; the number of steps at a given rate per minute to bring on intermittent claudication; the effect of foreign protein on the surface temperature and relief of symptoms; a diagnostic novocaine block to determine the vasomotor element, *etc.* All of these tests are of value in the diagnosis and the outline of treatment.

Differential diagnosis.—Here we often have our difficulties and not infrequently our first impression is incorrect. Some are border-line cases and occasionally remain as such, a definite diagnosis being impossible until the microscopical examination of a pathological specimen is made. On the other hand, many are clear-cut or have an overwhelming majority of symptoms and signs classifying them into one of the few groups that we recognize. We feel that many of the conditions such as erythromelalgia, acrocyanosis,

trophoneurosis, *etc.*, are probably not entities in themselves but simply represents a phase in disorders more readily understood. That there can be an element of sclerosis in cases of thrombo-angiitis obliterans seems reasonable when we consider that some of these patients may have had the disease for twenty years and have reached an age compatible with arteriosclerosis before symptoms of sufficient severity to bring about incapacity have overtaken them. That there is a definite vasomotor element in many of these cases there can be little doubt, and occasionally this phase almost outweighs the true underlying condition. This is particularly true when ulceration is pres-

Chart of differential diagnosis based on our cases of arterial disturbances of the extremities. There are necessarily exceptions to the rule

	Vasomotor disturbances	Thrombo-angiitis obliterans	Mönckeberg's arteriosclerosis	Senile arteriosclerosis
Average Age	30	40	50	60
Sex	Female	Male	Male	Both
Nationality	All	Hebrew	All	All
Duration of Symptoms	Years	Years	Months	Months
Extremity	Upper	Lower	Lower	Lower
Symmetry	Bilateral	One side at a time	Unilateral	Unilateral
Gangrene	Late	Late	Early	Early
Pulsating Vessels	Normal	None	None	Faint or None
Vessels by X-ray	No	No	No	Yes
Response to Foreign Protein	Marked	Marked	Slight	Slight
Response to Novocaine Block	Rapid and Marked	Slow and Mild	To be determined	Slight
Development Collateral Circulation	None	Good	Slight	Fair

ent. Whether the increase in pain caused by the exposed nerve endings stimulates the vasoconstrictor fibres; the discomfort which forces the patient to assume injurious positions such as holding the foot down over the side of the bed while resting; the lack of sleep, food and drink, or the abnormal increase in the use of tobacco brings about a vasomotor imbalance, is simply a matter of conjecture. It seems evident in a large number of our cases that any or all of these factors may influence the circulation through the sympathetic nervous system.

Treatment.—General considerations. The following routine measures are applicable to nearly all of these cases entering the hospital.

1. Rest in bed with feet and legs covered by a large cradle heated with electric lights.

2. A Balkan frame attached to the bed to aid the patient in moving about and to encourage exercise of the upper extremities and trunk.

3. Fluids up to four quarts a day, plus a liberal diet.

4. Careful daily hygiene for the feet; *i.e.* pressure points, particularly the heels, protected by a pillow under the legs. Lanolin applied to callouses and fissures, careful dressing of ulcerations, mild antiseptic bathing solution to the skin, and care of the nails and callouses by the chiropodist.

5. Buerger's postural exercises[3] as soon as the patient is adjusted to his surroundings.

A detailed description of our modification of these exercises is given in the following paragraph.

The first position should last theoretically as long as is necessary to blanch

FIG. 1.—Postural exercises: Position 1—duration two minutes. Note Balkan frame, "Buerger board" (McKittrick and Root),[4] heated cradle, and accurate timing.

the extremity. This varies considerably, but two minutes of elevation at 45° is usually sufficient. (Fig. 1.) The second position is carried out by the patient sitting on the side of the bed with the feet hanging down. During this phase, which should also last two minutes, the patient should systematically dorsiflex and extend the feet, then invert and evert them, then flex and extend the toes. (Fig. 2.) The third position is carried out with the patient lying flat in bed with the feet either under the electric cradle or, better still, with the feet on an electric pad and covered with a light warm blanket, and should last five minutes. (Fig. 3.) The three positions consist of a cycle and there should be from three to six cycles in a séance, with from two to four séances a day. The exercises should be carried out with accuracy, a timepiece at the bedside or in the patient's hand being essential.

The importance of these postural changes cannot be overestimated, as these alone probably do more to establish an adequate collateral circulation and maintain some motion and strength in the muscles and ligaments of the feet than all other measures.

It is interesting to note the large number of patients admitted to the hospital who have suffered so much pain that rest, nutrition and body fluids have been disturbed. Many of them, without sleep for weeks, become comfortable on these routine hospital measures alone. This is so striking, particularly in the arteriosclerotic group, that we have been very careful about

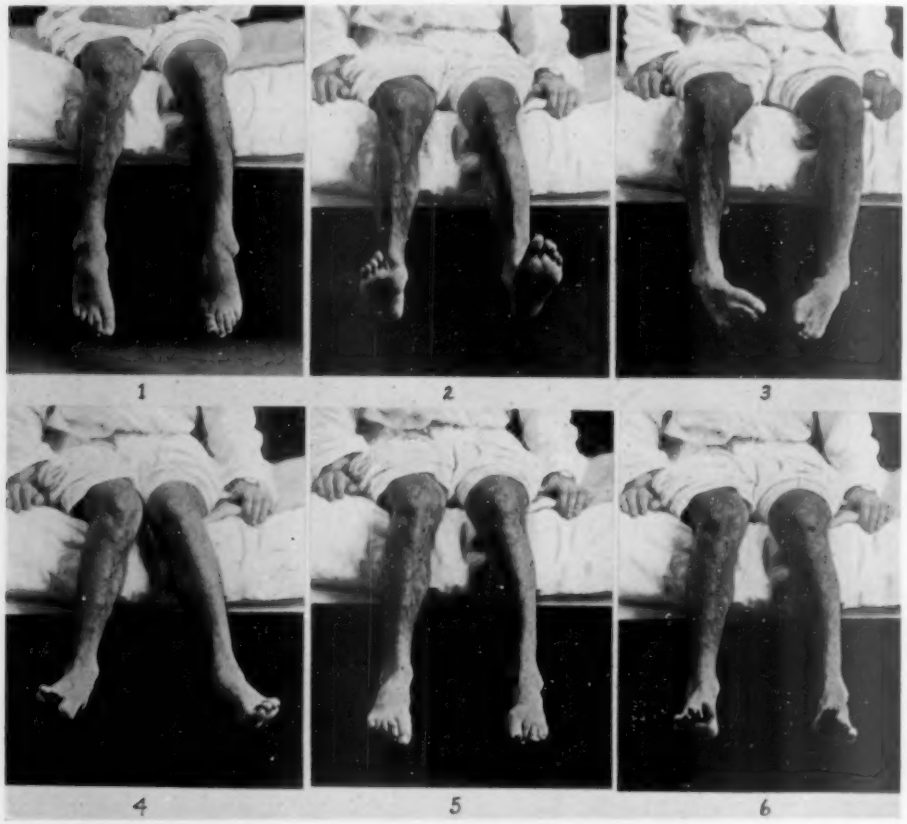

FIG. 2.—Postural exercises: Position 2—duration two to three minutes. Note the various active motions carried out in this position. A definite pause with relaxation is advocated between two and three and between four and five.

crediting improvement to other therapeutic measures which have received more or less recognition in other clinics, as well as our own. For this reason, no specific treatment is given the average case until an estimation of the benefit obtained from general measures is established. In other words, it is essential to await the improvement brought about by rest, fluids, nourishment, hygiene, exercises and routine hospital care before instituting any special form of therapy. Also, this delay is frequently necessary to form a true opinion as to the diagnosis and the type of treatment best suited to each individual case.

Special treatment.—Our experience with some of the various forms of special treatment advocated in other clinics has been somewhat limited, owing to the fact that they have not been applied to a sufficient number of cases to warrant more than an impression as to their adequacy. These include:

1. Ligation of the main artery (Lewis).[5]
2. Ligation of the main vein (Oppel,[6] Holman,[7] Morton,[8] Van Gorder.[9])
3. Periarterial alcohol injection (McClintic).[10]
4. Repeated intravenous sodium citrate solution.
5. Large quantities of Ringer's solution by duodenal tube.

All of these methods have had some trial in our clinic but have failed in the few cases in which they were used to give the desired results. Perhaps the

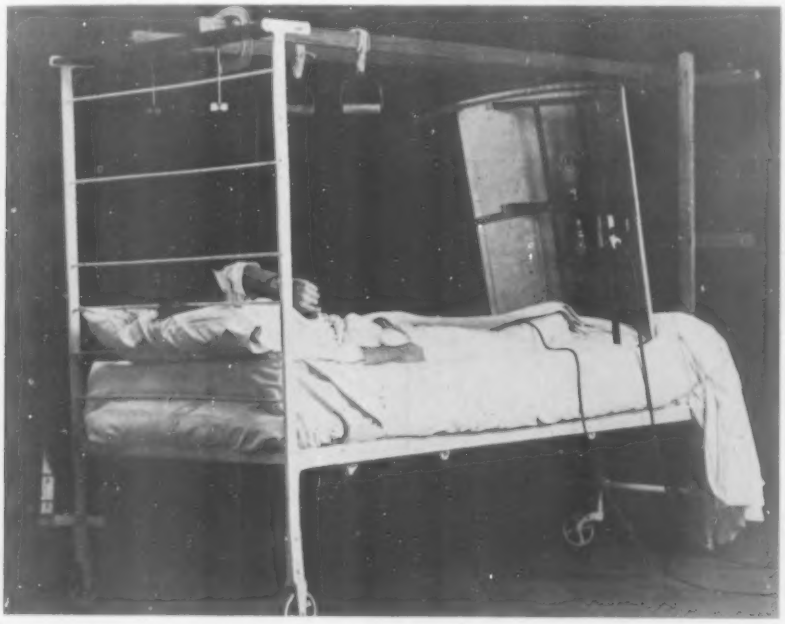

FIG. 3.—Postural exercises: Position 3—duration five minutes. Note electric pad and soft blanket.

fault is our own in that the cases treated were not well selected. We feel, however, that other therapeutic measures have been more valuable in our hands.

Our experience with some of the other forms of specific treatment has been sufficient to warrant an opinion as to their value. Among these are the following:

1. *Periarterial sympathectomy* (Leriche) was given a trial in twenty-one cases of varying types.[11, 12] No cases of true arterial obliteration were improved for a sufficient number of days to make the procedure worth while. One case of vasomotor disturbance following injury, probably a trophoneurosis (Leriche) was relieved of pain for nearly a year. With this background, it is difficult to be enthusiastic over the possibilities of periarterial sympathectomy or periarterial alcohol injection. That these procedures do

elevate the surface temperature and, in some cases, relieve pain for a short time, is certain, but these reactions are fleeting and can be accomplished by much simpler methods.

2. *Non-specific foreign protein* (typhoid vaccine intravenously).—Our experience with this form of treatment is still increasing and the results justify a continuation of its use in certain types of cases. Its use as a prognostic procedure as advocated by Brown,[13] is helpful, and its therapeutic value became evident to us while estimating the amount of vasomotor element in a case of bilateral gangrene of the fingers.[14, 15] There is some danger in its promiscuous use and we have reported the possibilities of producing a thrombosis if it is given carelessly, particularly in patients with advanced arterio-

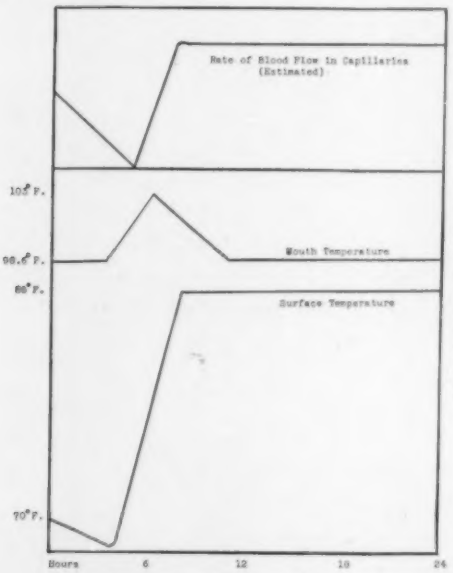

FIG. 4.—Non-specific protein reaction—(25 million organisms, mixed typhoid vaccine intravenously). Note slowing of capillary flow and decrease in surface temperature in early stage—which should be counteracted by preheating the extremities.[16]

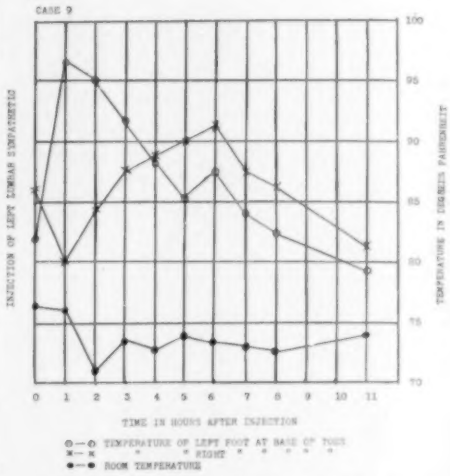

FIG. 5.—Chart illustrating typical temperature changes in novocain block of the left sympathetic trunk. J. C. White.[18]

sclerosis.[16] We have not been cognizant of any harm from it when properly used. When typhoid vaccine is given intravenously there is a characteristic reaction. (Fig. 4.) The peripheral circulation becomes slower during the first hour and associated with it there is a decrease in surface temperature and a generalized chill. As the mouth temperature reaches its peak, three to six degrees above normal level, the circulation in the peripheral vessels becomes speeded up to a degree far greater than it was originally. Associated with this phase is a rise in peripheral surface temperature equal approximately to three degrees (Fahrenheit) to each degree of mouth temperature elevation. This elevation of the surface temperature is maintained for several days after the mouth temperature has returned to normal. We have attributed the relief from pain and the improvement in the ulcerations to this increase in surface temperature which we have thought was brought

about by the action of foreign protein on the sympathetic nervous system. That there may be another and so far unexplained action of foreign protein seems possible, as illustrated by the following case:

A young man suffering from thrombo-angiitis obliterans in the right lower extremity was relieved of pain and impending gangrene by this method during a four months' stay in the hospital three years ago. Recently there has been a recurrence of the disease in the other leg. We obliterated the sympathetic influence by lumbar sympathetic neurectomy and the surface temperature of his foot has remained elevated to his maximum. In spite of this, his pain was more severe after the ganglionectomy and was relieved by the typhoid vaccine intravenously. This reaction is difficult to explain, inasmuch as the surface temperature could not be further raised beyond the mouth elevation. The possibility of a psychic factor cannot be overlooked. Ganglionectomy was done during a crescendo in the course of the disease. The increase of surface temperature seemed to hasten the development of gangrene in the tips of two toes.

We have used ganglionectomy in only three other cases of thrombo-angiitis obliterans and in these cases also, the healing of ulceration was extremely slow and in one case not influenced at all, in spite of the usual elevation of surface temperature to normal or more than normal.

In using typhoid vaccine intravenously we recommend the following technic and precautions: It should not be used in arteriosclerosis of a marked degree. It should never be given any patient without a preliminary heating of the extremities by means of electric pads, hot-water bottles and blankets at least one-half hour before giving the vaccines.[16] Dr. Frank Fremont-Smith[17] has shown that if this is done there is sufficient heat in the extremities to counteract the chilling process and consequent slowing of the blood-stream in the capillaries which otherwise occurs in the first phase of the reaction. If this precaution is taken we believe that thrombosis in the peripheral arteries will not occur. The first dose should be a small one, preferably about twenty-five million organisms of the mixed vaccine. If it is tolerated well, but the desired rise in mouth temperature to 103° F. does

	Vasomotor disease (Raynaud)	Thrombo-angiitis obliterans	Arteriosclerosis with and without diabetes	Totals
Number of Cases Treated	10	24	7	41
Average Age	25	40	60	
Average Duration Symptoms (Years)	2.9	4.4	0.4	
Number With Complete Disability	3	18	7	28
Minor Amputation Necessary	1	6	1	8
Major Amputation Necessary	0	3	4	7
Average Number of Treatments	3	9	8	
Average Duration of Treatments (Months)	5	8	4	
Improved	9	17	4	30
Not Improved	1	7	3	11
Complete Disability Now Including Cases c Major Amputations (after treatment)	1	6	4	11

A composite table showing the results of forty-one patients treated by non-specific foreign protein only. No other patients in this group have come to major amputations but three cases of thrombo-angiitis obliterans have returned with the disease in other extremities. These have also responded to treatment.

not occur, the next dose can be increased accordingly. It is important to be sure that the vaccine gets into and not around the vein. It should be given slowly. It is not necessary to increase the dose each time, as the same dose will produce the same reaction in the same individual indefinitely, if given properly and not more often than once in seven days. Patients should not be treated in the office or the out-patient department but should be in the hospital for at least twenty-four hours following the injection. The headache can usually be controlled by aspirin if given before the reaction begins. Opiates are occasionally necessary. Many patients who come in more or less regularly do not require any sedative.

As far as treatment is concerned, non-specific foreign protein still has its uses, although some cases respond better to other methods, as will be shown later. Although we still use it as a prognostic test to determine the effect of a surgical attack on the sympathetic nervous system, we believe that Dr. J. C. White[18] has given us a more accurate method of estimation by his novocaine block. He has found that novocaine injected into the main nerve, or the sympathetic ganglia or into the spinal canal, gives a temporary elevation of surface temperature in the extremity influenced, identical with that of ganglionectomy. Not infrequently the test may be made with spinal anæsthesia. If the desired rise in surface temperature is obtained, ganglionectomy may be carried out under the same anæsthetic. If the reaction is not adequate in spite of good anæsthesia, an amputation may be done under the same anæsthetic. We believe that the accuracy of this test and its simplicity makes it more valuable than any other yet devised. (Fig. 5.)

Alcohol injection of peripheral nerves.—Several years ago Silbert[19] advocated alcohol injection of peripheral nerves at the level of the malleoli for relief of pain in thrombo-angiitis obliterans. We tried this method in 1923 and found that wounds would not heal at this level, and therefore gave up the procedure. In the summer of 1928 we saw a patient with arteriosclerotic gangrene in his one remaining foot, who had received an alcohol injection in part of the sciatic nerve, seven months previously in another city. This was associated with toe drop and a certain amount of loss in muscle action. The painless gangrene, however, made an impression on us, as we watched a collateral circulation develop, to a point allowing weight-bearing four months later. This patient has since regained motion in the foot, although it took about eighteen months for the nerve to regenerate. His foot is useful and painless today, in spite of the loss of parts of three toes and the extra burden thrown upon it by the artificial leg worn on the opposite side. Smithwick and White[20] have developed a method of isolating and injecting the sensory nerves in the leg in such a manner as to produce anæsthesia of the foot without disturbing any of the muscular elements except the intrinsic muscles of the foot. We are so impressed with the value of this method of treatment that we feel it to be a distinct contribution to the management of these cases. The relief of pain is worth while, but there are other factors

which indicate its true importance. Dressings on these painful ulcerations were almost impossible from a surgical point of view. Exercises were not well borne on account of the increase in pain in the extreme positions. Rest was disturbed as well as nutrition and body fluids. When the pain is relieved, all these factors are eliminated and progress is usually rapid. In addition to this, we have noted that there is an increase in surface temperature, sometimes not as marked as that following novocaine block at a higher level, or when typhoid vaccine is given intravenously, but a distinct rise, showing, we believe, that the pain from the ulceration may act on the sympathetics or that there is some vasomotor influence at this low level through the sensory nerves themselves.

Alcohol Injection of Peripheral Nerves for Relief of Pain
December 1, 1929

Middle-aged (thrombo-angiitis and Mönckeberg)—9 cases
Average Age about 40

	No. Cases	Good Result	Major Amputation
Popliteal Pulsation +	3	3	0
Popliteal Pulsation −	6	4	2
	9	7	2

Senile Arteriosclerosis..... 7 cases
Average Age about 70

	No. Cases	Good Result	Major Amputation
Popliteal Pulsation +	3	2	1
Popliteal Pulsation −	4	1	3
	7	3	4

Total Cases—16 Relieved—10 (62.5%)

Observing our cases it seems safe to anæsthetize any foot in the presence of a palpable popliteal artery. The alcohol should not be spilled in the tissues around the nerve, and care must be exercised to avoid trauma to accompanying vessels. About one centimetre of the nerve should be thoroughly infiltrated with the alcohol. In rare cases there will be disappointing results, in that the numbness and tingling in the foot, as the patient walks, will be complained of more bitterly than the symptoms for which the treatment was instituted. This was true in an arteriosclerotic with pulsating vessels and erythromelalgia. We have expected and looked for trophic ulcers following this treatment and have, up to date, two such lesions in our clinic. This may be avoided if proper protection from sponge rubber arch supports and properly fitting shoes are furnished. The nerve regenerates in a variable length of time, dependent upon the amount infiltrated, usually not early enough to interfere with the healing of ulceration and the establishment of an adequate collateral circulation.

Ganglionectomy (sympathetic neurectomy).—Following the visit of Royle and Hunter to this country several years ago, their technic of ramisection for spastic paraplegia was used in operating on a certain number of cases in this vicinity. Dr. W. J. Mixter called my attention to the striking increase in surface temperature of the foot on the operated side in one of these patients, five years ago. About this time Adson and Brown[21] published their results on a case of Raynaud's disease and later reported five cases of thrombo-angiitis obliterans, four of whom had been relieved by lumbar ganglionectomy. This was followed by further researches on their part, developing a technic which was successful on the upper extremity as well.[22] We have found this procedure amazingly successful in true vasomotor disorders. Our limited experience with the procedure in thrombo-angiitis obliterans, as shown above, is not so convincing. However, it is an extremely valuable contribution and undoubtedly we can expect *more* from it than from periarterial sympathectomy, and in the vasomotor group *more* than from non-specific foreign protein.

We advocate operation on one upper extremity at a time, as there is some danger of injury to the pleura; also, these wounds are prone to have a dead space difficult to close, and hæmatoma may develop. Bilateral lumbar ganglionectomy can usually be safely carried out and as the approach is through the abdomen, there will probably be less risk in doing both sides at one stage than to make two procedures of it. In the upper extremity the first and second dorsal ganglia and intervening trunk are removed. In the lower extremity the third, fourth, and fifth lumbar ganglia (the latter two being together) and the intervening trunk are excised. These are approached by rolling the cæcum toward the mid-line on the right, and the sigmoid in on the left. The ganglia lie closely adherent to the vertebra and are never reflected with the fat and connective tissue over them. The dorsal ganglionic chain may be reflected with the pleura but usually remains in contact with the vertebral column.

Sympathetic Ganglionectomies—1929

	Upper		Lower			
Disease	Bi-lateral	Uni-lateral	Bi-lateral	Uni-lateral	Total Sides	Results
Vasomotor (Raynaud's)	1	1	3	–	9	All Excellent
Thrombo-angiitis Obliterans	0	–	1	1	3	Doubtful
Polio—With Vasomotor	0	–	1	3	5	Doubtful
Atrophic Arthritis	–	2	–	–	2	Improved
Trophic Ulcer	–	–	–	1	1	Improved
Angina Pectoris		3				
Spastic Paraplegia		1				
Tabetic Crisis		1				
Erethema Induratum		1	Bilateral			
Total Patients—22			Total Ganglionectomies—29			

Some of these cases have been operated upon by Dr. W. J. Mixter of the Neurosurgical Service.

Lumbar sympathetic neurectomy in the presence of an open ulceration may be followed by disastrous results, inasmuch as a virulent streptococcus may be dormant in such a lesion. In one case, a boy of eighteen, with marked vasomotor changes in all extremities and an ulceration above the internal malleolus that had resisted all other therapy, death occurred forty-eight hours following lumbar sympathetic neurectomy, this being our only fatality in thirty patients, representing over forty ganglionectomies to date. Streptococcus viridens was recovered from the operative field and from the heart blood at autopsy. We now culture all such lesions with great care before subjecting these patients to any radical operation. It is our belief that the lymphatics in the neighborhood of the sympathetic nervous system supplying the lower extremity may harbor virulent organisms which can easily be set free by the operative procedure.

Restoration of function.—It may appear presumptuous to suggest that care should be used in getting these patients back on their feet. We have seen nothing in the literature along these lines, and one may assume that the patients themselves should know their limits of safety. Many of these patients, however, are of low intelligence either through age, or inheritance. We also find that our house-officers have little or no idea of the proper reëstablishment of a patient's normal activities. When the time comes for the patients to begin getting about, after they have been in bed for several weeks, we limit their walking, at first, to one minute out of the hour. The remainder of the time is spent with the legs elevated to a horizontal. If this is well tolerated, it is gradually increased and the patient not discharged until he can walk for five minutes at a time without cyanosis and swelling. Patients with amputations whose conditions warrant a prosthesis are fitted with temporary appliances and taught to use them before leaving the hospital. We have seen cases who have lost one leg return within two weeks with symptoms in the remaining leg that led to gangrene and amputation simply because proper instructions as to gradual return to function were either carelessly explained or were unheeded. If routine measures are used along these lines, many difficulties in rehabilitation will be solved.

SUMMARY AND CONCLUSIONS

Cases with mild symptoms may carry on for an indefinite period by occasional advice in the out-patient department concerning rest, hygiene, care of the feet, proper protection with lamb's wool and woolen stockings, and exercises to be done at home. A suitable ambulatory case of vasomotor disorder or thrombo-angiitis obliterans may spend twenty-four hours in the Emergency Ward occasionally, at which time a protein shock with typhoid vaccine intravenously may be given.

Those cases of sufficient severity to cause complete disability, as well as those who need constant observation, are treated in the hospital. They are given any emergency attention necessary and are started on the routine measures of rest, heat, hygiene, fluids, food and exercises. After stabiliza-

tion, specific treatment is instituted according to the condition. Advancing infection is drained, and advancing lymphangiitis amputated. Non-specific foreign protein is tried in thrombo-angiitis obliterans, peripheral nerve alcohol injection in cases of intractable pain, and sympathetic ganglionectomy carried out in advanced vasomotor disorders.

In chronic cases an individual time limit is set and if improvement is not evident in a given time (one to eight weeks, depending upon the condition and contributory factors), more radical measures are adopted. If a person with a hopeless extremity which has remained at a standstill or definitely grown worse in spite of treatment, refuses amputation, then through the Social Service proper disposal is arranged, with all the helpful advice for comfort that we can give them.

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DISCUSSION: DOCTOR JOHN J. MORTON, of Rochester, N. Y., said that at the University of Rochester they had been developing tests by which it is possible to differentiate the relative proportions of obliteration and spasm in cases of peripheral vascular disease. Surface temperature readings were made with a thermo-couple on the exposed soles and toes of individuals with clinically normal blood vessels. These patients were about to be operated upon for some general surgical condition not related to the vascular system. When spinal anæsthesia was given, all nervous impulses to the feet were abolished and the normal vessels were released from sympathetic vasoconstriction effects. In a group of twenty-two patients of this type it was observed that before anæsthesia, there was a definite vasoconstrictor gradient, the surface temperature readings recording lower from a level just below the knee until the lowest temperatures were reached on the toes. Spinal anæsthesia abolished these differences in surface temperature readings and within a short time all surface temperatures had reached a considerably higher level. There was only a slight variation in the upper and lower limits of these higher surface temperature readings. We think that these readings under spinal anæsthesia represent the maximum vasodilatation possible and we refer to them as the "normal vasodilatation level." The only exceptions so far observed by us in patients with normal vessels were in cases of fever where the normal vasodilatation was already attained; and in cases of advanced carcinoma. In these latter patients there was a higher than normal surface temperature reading at the start and the surface temperature readings dropped lower after spinal anæsthesia.

The normal vasodilatation level having been established, it is possible in case of a peripheral vascular disease to record the surface temperature readings after spinal anæsthesia and to thus see how nearly the readings come to the normal level. The difference between the normal level and the level reached in the diseased limb represents the degree of obliteration—"obliteration index."

Lantern slides were shown illustrating the normal vascoconstrictor gradient; the normal vasodilatation level; and the obliteration index as determined in patients with peripheral vascular disease.

After lumbar sympathectomy the vasoconstrictor effect is completely removed and the surface temperature readings are consistently and uniformly maintained. Spinal anæsthesia has no effect on the surface temperature of such a limb unless some sympathetic fibres have been overlooked at operation. When a unilateral operation has been performed this difference between the operated and unoperated limbs shows strikingly. It is also possible to show in such individuals that after cooling the surface temperature recovers much more quickly on the sympathectomized side than on the side with the intact sympathetic nerve supply. Lantern slides were shown to illustrate these points.

By these methods the relative degrees of sympathetic vasoconstriction and organic obliteration can be determined in any case of peripheral vascular disease. We are continuing our studies to develop simplification of the methods. The Taylor Instrument Company of Rochester has helped us in making a simplified form of surface temperature thermometer for this work. It is here in case anyone wishes to see it.

Dr. W. J. Mixter (Boston): said that the development of the circulatory clinic at the Massachusetts General Hospital has not only paralleled some of the neurological work there but Doctor Allen and he had worked together on some of these problems. The circulatory clinic at the Hospital has shown its value not only in the handling of the cases treated by injection of varicose veins but in many other ways. These attacks on the sympathetic nervous system in circulatory diseases offers a field which is going to develop more and more as time goes on.

Dr. Arthur W. Allen added that the personnel of the circulatory clinic consists of five men from the surgical service who are either interested in the subject or show signs of possible research in this field, one member from the medical service who is particularly interested in diabetes, a representative of the orthopedic service, and a chiropodist. It is essential to have complete coöperation of the men on this assignment as well as the entire hospital staff.

GENERAL SURGICAL CONTRIBUTIONS

NOT PRESENTED BEFORE THE AMERICAN SURGICAL ASSOCIATION

THE RÖNTGEN DIAGNOSIS OF ILEUS

By Alton Ochsner, M.D., and Amedee Granger, M.D.

of New Orleans, La.

FROM THE DEPARTMENTS OF SURGERY AND RÖNTGENOLOGY, CHARITY HOSPITAL, THE DEPARTMENT OF SURGERY, SCHOOL OF MEDICINE, AND THE DEPARTMENT OF RADIOLOGY, GRADUATE SCHOOL OF MEDICINE OF TULANE UNIVERSITY

The early diagnosis of ileus is of utmost importance in order that proper therapy might be instituted before marked changes have occurred in the intestinal wall or a severe toxæmia has developed. The necessity of early

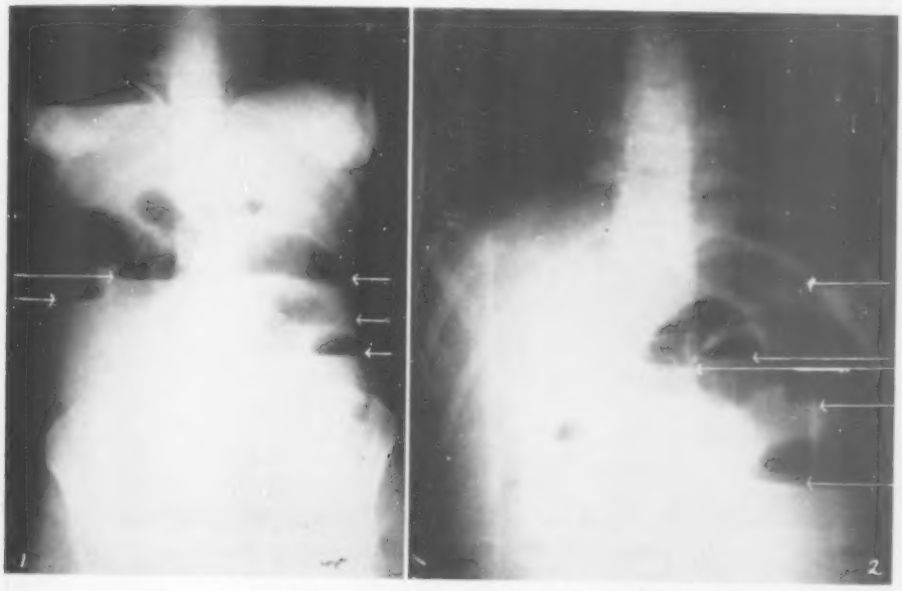

Fig. 1.—M. K., aged forty-three years. Plain röntgenogram of the abdomen of a patient who seventeen days previously had been operated upon, at which time a hysterectomy was performed. Three days before X-ray patient began to have abdominal pains, colicky in nature. Röntgenogram shows dilatation of the intestine with multiple fluid levels, located principally in the upper portion of the abdomen. From patient's history and the characteristic X-ray findings a diagnosis of intestinal obstruction was made. An obstruction was found at the time of operation in the ileum, producing marked dilatation of the gut proximal to it.

Fig. 2.—T. F., aged nine years. Röntgenogram of abdomen of patient who two days previously began having cramp-like pains in the abdomen associated with vomiting and obstipation. X-ray examination—anterior-posterior röntgenogram of the abdomen with the patient in the upright position shows the presence of multiple fluid levels in the upper left portion of the abdomen. A diagnosis of intestinal obstruction high in the intestine was made. At operation a mechanical obstruction produced by fecalith of the ileum was found.

recognition and early relief of ileus is demonstrated by a series of cases recently reported by Miller.[1] Of 343 cases, those which were operated upon within twelve hours showed a mortality of 29.4 per cent; those operated upon with in twenty-four hours, a mortality of 52.9 per cent.; within thirty-six hours, 50 per cent.; within forty-eight hours, 59.6 per cent.; within seventy-two hours, 63.4 per cent.; within ninety-six hours, 72.8 per cent.;

and over ninety-six hours, 84 per cent. In a similar series of cases studied by Brill,[2] seventeen cases coming to operation within 12 hours of the onset of symptoms presented no mortality. In sixteen cases coming to operation between twelve and twenty-four hours after the onset of symptoms, there was a mortality of 12.5 per cent. In eighteen cases coming to operation within from twenty-four to forty-eight hours, there was a mortality of 61.1 per cent. It is generally accepted by surgeons today that early operation with relief of obstruction is the only practical treatment of mechanical ileus. In order that an operative procedure may be performed at the proper time it is essential that the diagnosis be made early.

Of greatest importance as concerns the diagnosis in ileus is the history,

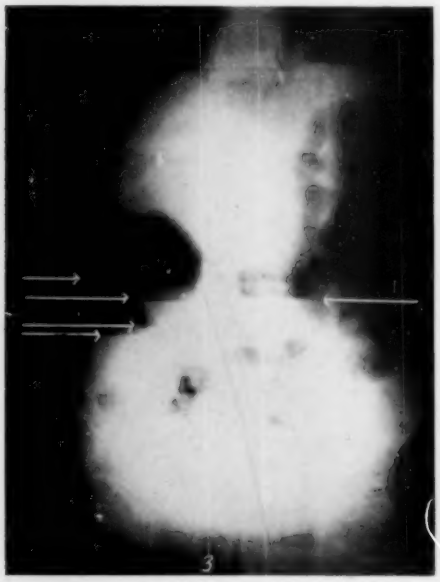

FIG. 3.—Plain röntgenogram of F. S., aged seventy years. For twenty years patient has had a hernia. Thirty hours previous to admission to hospital was taken suddenly with severe pain in the abdomen associated with vomiting. Pains cramp-like in character. Röntgenogram shows the presence of fluid levels in both sides of the abdomen most marked in the upper and outer portions of the right side. There is some increase in the gas content in the small gut. At operation an obstruction in the region of the sigmoid flexure of the colon was found.

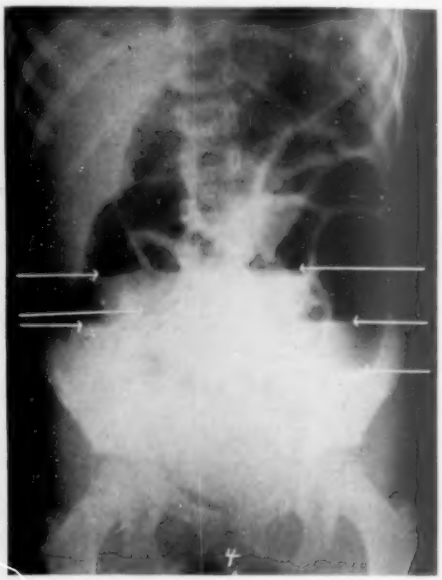

FIG. 4.—Plain röntgenogram of the abdomen of H. C., aged six years, who two days prior to admission to the hospital was awakened suddenly with pain in the abdomen near the umbilicus. Patient vomited and has been obstipated since. Abdomen distended. Röntgenograms taken with the patient in the upright position shows marked dilatation of the loops of the intestine with parallel transversely coursing loops of bowel in the upper left portion of the abdomen. Two of these loops show typical serrated outlines. There are numerous fluid levels present in various portions of the abdomen. At autopsy and enterolith at about the junction of the jejunum with the ileum was found producing complete obstruction.

which is usually quite typical and characteristic. The history of pain, which is intermittent and colicky in type, associated with varying degrees of abdominal distention and obstipation, is very suggestive of a mechanical obstruction. Much more difficult, however, is the diagnosis of ileus developing post-operatively, which may be either of the mechanical or adynamic variety. Here, because of the operative trauma, it is difficult to evaluate the symptoms and signs presented by the patient. Any additional diagnostic pro-

cedure in this or other types of cases in which the diagnosis may be obscure is of distinct value.

It is generally appreciated at the present time by both surgeons and röntgenologists that the ingestion of opaque substances by patients in whom a suspected obstruction is present is unwise and a dangerous procedure. It has been the experience of most röntgenologists and surgeons that occasionally an incomplete obstruction may be transformed into a complete obstruction by the administration of contrast substances by mouth. The injection of an opaque medium into the rectum as an enema is a justifiable procedure and should be employed in those cases in which an obstruction of the large bowel is suspected. This procedure is, however, of value only in those cases in which the obstruction is located distal to the ileocecal valve.

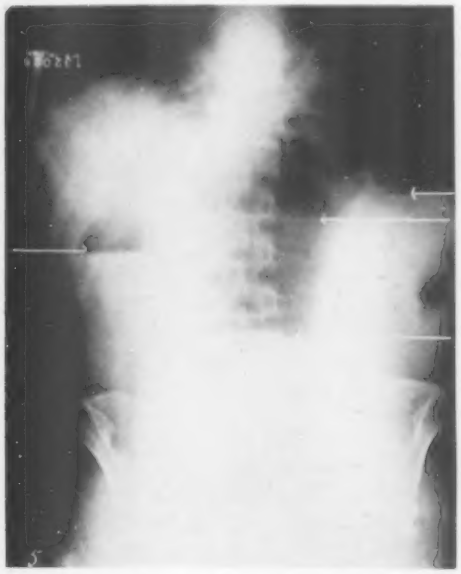

FIG. 5.—J. C., aged thirty-nine years. Plain röntgenogram of a patient who began having colicky pains in the abdomen. X-ray shows marked distention of the colon with several fluid levels, located in the periphery of the abdomen. Operation revealed a volvulus of the sigmoid colon.

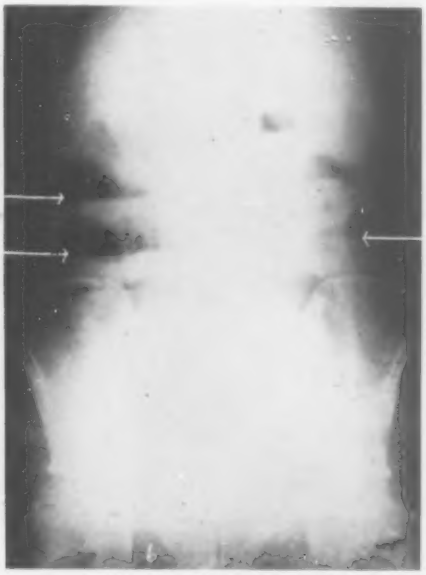

FIG. 6.—Abdominal röntgenogram of F. M., aged twenty-seven years, who for twenty-four hours had had severe abdominal pain, not colicky in nature. Röntgenogram shows numerous fluid levels within abdomen. Operation revealed a diffuse peritonitis due to a perforated gastric ulcer. This is an example of a paralytic ileus.

In 1911, Schwarz[3] advocated the administration of small amounts of barium to patients with suspected obstruction, following which a röntgenogram of the abdomen was taken with the patient in the upright position. In this way numerous fluid levels produced by opaque substance below and capped above by gas were visualized in the abdominal röntgenogram. Even though barium was administered in each of the cases examined by Schwarz,[3] he was able, in several cases, to make a diagnosis of intestinal obstruction even before the barium was given, because of the multiple fluid levels. Two years later, Assmann[4] reported five cases of obstruction of the small intestine, proved to be so by autopsy or operation, in which röntgenograms made of the abdomen without the administration of contrast media showed long and frequently parallel loops of gut which were markedly distended, coursing either obliquely or transversely across the abdomen. Assman[4] made no mention of the position which the patient assumed when the

röntgenograms were made, but in all the röntgenograms which were reproduced multiple fluid levels were present.. In the same year, Hoesslin[5] stated that plain röntgenograms of the abdomen were valuable in diagnosing acute intestinal obstruction and stressed the presence of multiple fluid levels in the abdominal röntgenogram. In 1915, Case[6] emphasized the possibility of making a correct diagnosis of intestinal obstruction röntgenologically by the gaseous distention of the intestine. Case[6] was the first American to call attention to this valuable procedure and merits credit for the pioneer work which he has done in this particular field. He emphasized especially the increase in diameter of the loops of small bowel and the parallel course of the coils of intestine in obstruction of the small intestine. As a characteristic finding he described the serrated contour of the bowel. In his original publication, Case[6] made no mention of the value of the presence of fluid levels in making a diagnosis of intestinal obstruction. The importance of the presence of multiple fluid levels in röntgenograms of the abdomen was, however, stressed by Weil,[7] who believed that this procedure was especially valuable in those cases in which the obstruction was within the small bowel, because normally no air is contained within the jejunum or ileum. Bensaude and Guénaux[8] emphasized the value of this procedure in the diagnosis of stenoses of the large intestine. They found that in obstruction within the large intestine typical collections of fluid capped above by gas could be found. Their best röntgenograms were obtained when the fluid and gas were in the ascending colon from stenosis of the descending colon or sigmoid. Kloiber[9] believes that the presence of multiple fluid levels in the abdomen is pathognomonic of intestinal obstruction. He advocates the taking of the röntgenogram with the patient lying on the side in those cases in which the patient is too ill to sit up. He believes that a positive finding can be obtained within five and a half hours after the beginning of the obstruction. Similar cases have been reported by Milhaud.[10] Within the past three years there have appeared in the American literature, observations by Kalbfleisch,[11] Meyer and Brams,[12] Davis,[13] and Rabwin[14] concerning the use of X-ray examination in the diagnosis of acute ileus. With the exception of Kalbfleisch,[11] these authors have stressed only the presence of gas in the intestines in abnormal amounts and in unusual areas. Kalbfleisch,[11] however, emphasizes the importance of the presence of multiple fluid levels as diagnostic in intestinal obstruction. Case,[15] in 1927, again emphasized the presence of abnormal amounts of gas in abnormal positions. In this publication the possibility of visualizing collections of fluid capped above by gas was mentioned but not especially emphasized. Recently Martens[16] and Hintze[17] have advocated this procedure and have stressed the presence of fluid levels as being especially diagnostic.

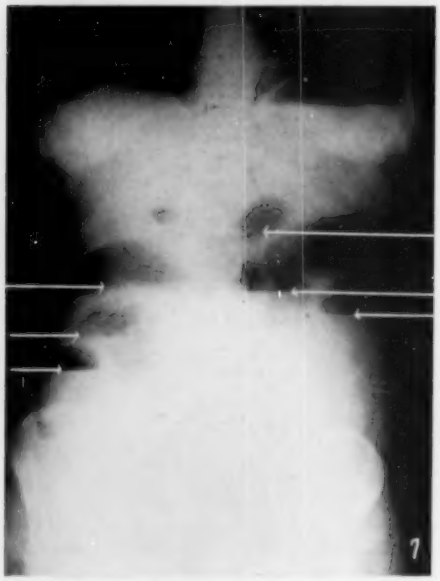

FIG. 7.—Röntgenogram of abdomen of M. K., aged forty-three years, who seventeen days previously had had a hysterectomy performed. For two days colicky pains in abdomen. Röntgenogram shows multiple fluid levels in the upper part of abdomen. At operation an obstruction of the ileum caused by adhesions was found.

Pathologic physiology.—In acute ileus, whether it be of the mechanical or the adynamic variety, there occurs in the intestine a marked dilatation of the gut with an accumulation of an abnormal amount of gas and fluid. This is due in part to obstruction and stagnation of the normal intestinal contents and in part to the lack of absorption of the intestinal contents and to an increase in secretion. Zuntz and Tacke[18] have

shown that normally the gases contained within the intestine are absorbed into the blood-stream and eliminated by way of the lungs. Only a small proportion, about one-tenth of the total gas, escapes through the anus. Any interference with the blood supply of the gut diminishes absorption of the gas, thereby producing overdistention of the intestine. In all cases of ileus, irrespective of the variety, there is some interference with the blood supply of the gut, even though such interference may be entirely intramural. McIver and his associates[19] have shown that if a loop of intestine is distended with air, carbon dioxide is diffused from the blood into the intestinal lumen. Müller[20] has demonstrated that in paralytic ileus, at least, there is a marked increase in the secretions from the gastro-intestinal tract and its appendages. On the other hand, Enderlen and Hotz,[21] Braun and Boruttau,[22] and Esau[23] have found that in intestinal obstruction, absorption from the gut is diminished. From these findings it is evident that very early in the course of ileus, irrespective of the variety, there is an increased accumulation of both gas and fluid within the lumen of the gut. Kloiber[9] believes that such an accumulation is sufficient within five and a half hours so that it can be demonstrated röntgenologically. Case[15] states that enough fluid and gas are present within

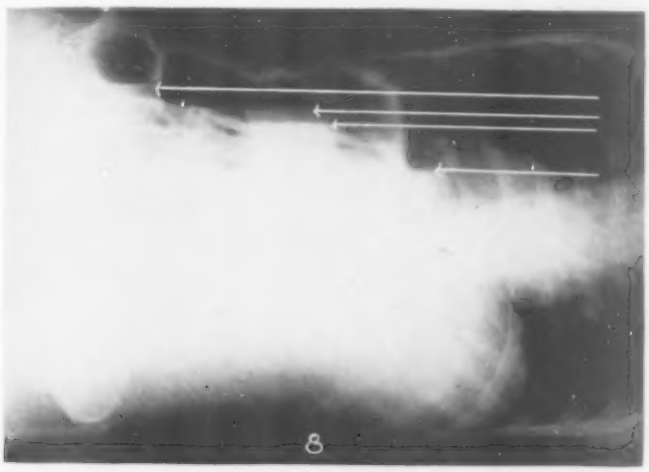

FIG. 8.—Anterior posterior röntgenogram of L. O. taken with patient lying on the right side. For two days patient had had cramp-like pains in the abdomen associated with vomiting. Only slight distention of the abdomen. Röntgenogram shows accumulation of fluid and gas with the production of multiple fluid levels. Operation revealed an obstruction in the lower ileum due to adhesions.

six to eight hours after the establishment of obstruction to be visualized by means of the Röntgen-ray. Wangenstein and Lynch[24] found that within four to five hours after complete occlusion of intestines in animals, there was röntgenological evidence of gaseous distention of the intestines proximal to the obstruction. Whereas they found also an accumulation of fluid proximal to the obstruction, this was less marked than is seen in the human unless saline was administered subcutaneously. In humans, however, the accumulation of fluid as well as gas is a prominent feature in obstruction. In two animals in which a strangulation was associated with the obstruction there was distention of the intestinal loops proximal to the obstruction, but none of the strangulated loops.

Technic.—Schwarz[3] originally advocated the taking of röntgenograms with the patient in the upright position in order that a contrast might be obtained between the fluid below and the gas above. Assmann,[4] Case,[6], [25], [26] Weil,[7] Davis[13] Meyer and Brams,[12] and Rabwin[14] advocated that a röntgenogram be taken with the patient in the supine position. Even though abnormal collections of gas as regards amount and position can be ascertained in most cases of obstruction with the röntgenogram taken with the

patient in the supine position, it seems desirable to the authors to make use of the contrast which may be obtained at the junction of fluid and gas when a patient is placed in such a position and the röntgenogram taken in such a manner as to visualize the surface of the fluid. This may be accomplished by obtaining an anterior-posterior view of the abdomen with the patient in the upright position advocated by Schwarz,[8] Hoesslin,[5] Weil,[7] Bensaude and Guénaux,[3] Kloiber,[9] Milhaud,[10] Wynen,[27] Kalbfleisch,[11] and Ochsner.[28] In those cases in which the patient is too ill to assume the upright position, as is frequently the case in intestinal obstruction, the following procedure may be employed. With the patient in a supine position a lateral röntgenogram of the abdomen is made, or with the patient lying on either side an anterior-posterior röntgenogram is made (Figs. 8 and 9). This has been advocated by Kloiber,[9] Wynen,[27] recently by Case,[15] and Martens.[16] Röntgenograms obtained in this manner produce a picture which is so characteristic of intestinal obstruction, either the mechanical or the adynamic variety, that a diagnosis can be readily made. The presence of numerous fluid levels in various parts of the abdomen is pathognomonic of ileus. If these fluid levels are located principally in the central portion of the abdomen, the obstruction may be con-

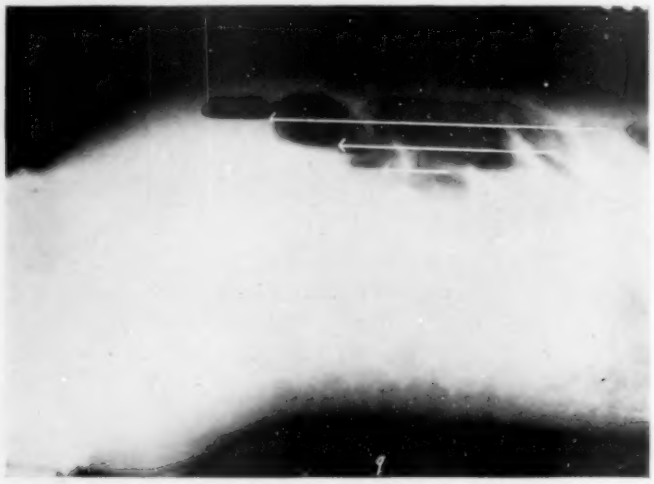

FIG. 9.—Lateral röntgenogram of L. O. (Fig. 8) taken with patient lying in supine position. Multiple fluid levels are evident.

sidered to be in the small bowel; if the fluid levels are located around the periphery of the abdomen, the obstruction is probably relatively low in the large bowel. The finding of multiple fluid levels in the abdomen is much more striking than the increase in the amount of gas which is seen in those cases in which the röntgenograms are taken with the patient in the supine position. Characteristic of these plates is dilatation of the loops of gut to two to three times the normal size, which course either transversely or obliquely across the abdomen and a serration of the gut outline when the obstruction is in the small intestine. These findings have been emphasized by Assmann,[4] Case,[6] Meyer and Brams,[12] Davis,[13] and Rabwin.[14]

Within the past two and a half years, plain röntgenograms of the abdomen in cases of probable intestinal obstructions have been made in thirty-two cases admitted to the Charity Hospital, New Orleans. The results obtained by the use of this procedure have been very gratifying. In twenty of the cases, the clinical picture was definite enough that a preoperative diagnosis of ileus could be made with reasonable safety. The

röntgenogram was obtained as confirmatory evidence. In twelve cases, the röntgenogram was of distinct value as a diagnostic procedure, permitting a correct diagnosis even though the clinical symptoms and signs were not diagnostic.

In all but four cases it was possible for the patient to assume the upright position, *i.e.*, sitting with the radiographic plate against the abdomen during the exposure of the film. In each instance the exposure was made at seven feet.

SUMMARY

1. In acute ileus the administration of opaque media by mouth is dangerous.

2. Plain röntgenograms of the abdomen without the administration of contrast media are valuable in diagnosis of acute ileus.

3. Within a few hours after an inception of an intestinal obstruction there is an abnormal accumulation of gas and fluid proximal to the obstruction.

4. Even though gaseous distention of the intestines as revealed röntgenologically is indicative of intestinal obstruction, the finding of multiple fluids due to the presence of fluid capped above by gas is much more striking and therefore more diagnostic. In order to demonstrate this, röntgenograms should be taken in such a manner that junction of the fluid with the gas may be visualized, *i.e.*, an anterior-posterior view with the patient in the upright position or lying on either side, or a lateral view with the patient lying in a supine position.

5. Results obtained in thirty-two cases of ileus in which this diagnostic procedure was used are reported.

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FIBRO-SARCOMA OF THE MEDIASTINUM

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of Marshfield, Wis.

Great progress in chest surgery cannot be obtained until thoracotomy has become a safe procedure and until diagnostic thoracotomy has left us in no doubt. As no general surgeon has done a sufficient number of thoracotomies to form an opinion entirely acceptable to others, it will not be amiss, nay, it becomes the duty of every one who has had experience with thoracotomies to report his experience. It is with this in view that I here report the following case.

A man, H. C. K., fifty years of age, married and father of eight children, was operated upon for gall-stones in 1916. Gall-stones were removed and the appendix vermiformis also. The gall-bladder was not removed. Good recovery. No recurrence. September 17, 1927, he consulted Dr. W. D. Sexton, complaining of general weakness, general malaise, slight cough, and shortness of breath, and at times pain in his left chest below the heart. No bloody expectoration, no night sweats. His face was slightly flushed. There was limited respiratory movement over the entire left chest, also flatness on percussion, except over the upper and anterior part where there was resonance. Vocal fremitus absent. Breath sounds very distant, hardly audible. No râles. Percussion of right chest is hyper-resonant. Here breath sounds are slightly exaggerated, no râles. Heart inside of left nipple line. Temperature normal. Fluoroscopic examination gave darkness over entire left side of chest (Fig. 1).

He was subjected to aspiration September 19, 1927. Physical findings as before. A needle inserted in the mid-axillary line between the seventh and eighth ribs was without results, as also was the insertion in the fourth intercostal space, slightly more posterior. A third puncture made posteriorly about four inches from the spine was positive and about 1000 cubic centimetres of a bloody fluid was withdrawn. The patient felt easier after this. Five days later additional fluid to the extent of 700 cubic centimetres was aspirated.

An X-ray examination on September 20 and October 1 showed almost the same picture as was obtained before punctures were made, except that now it was apparent that the heart and mediastinal contents were displaced more decidedly to the right than was noticeable before the aspirations.

October 3, feeling much improved, he returned to his home. On October 21, while at his office, he became quite excited regarding a business transaction. He talked incessantly and irrationally. The next day he was decidedly better and was feeling well. The pulse and temperature were normal. On the morning of October 24, he became very irrational. He was taken to the hospital and his nervousness controlled by morphine and scopolamine. Glucose was given per rectum, and the patient returned to a normal condition in about two days. From then on he relapsed at intervals into a state of irrationality, which at one time at least increased to maniacal proportions.

Examinations of his urine were made frequently. It occasionally showed a light trace of acetone. He had a trace of albumen but at no time showed evidence of uræmia. On two or three occasions his pulse would suddenly become very weak and thready, but under the influence of morphine would improve and become normal again. Two aspirations resulted in the removal of but small amounts of fluid. The doctor had the sensation that the needle entered a solid mass or tumor, and the patient was advised to

consent to an exploratory thoracotomy in the hope that this tumor might be removed. The case was then referred to Dr. K. W. Doege for exploratory thoracotomy.

November 7, 1927, under local para-vertebral anæsthesia, the patient being in a semi-sitting, semi-reclining position and on his right side, an incision about ten inches in length was made, beginning posteriorly at the level of the fourth rib and sloping downward and forward ending at the tenth rib in the anterior axillary line. The skin and muscles were reflected to both sides and the sixth, seventh, eighth and ninth ribs exposed and laid bare. These ribs were resected sub-periosteally to the extent of about four to six inches. After all hæmorrhage had been stopped the chest cavity was opened by forming a horseshoe flap of the intercostal muscles and beds of the ribs, the base being at the lower border of the fourth rib. A turbid, milky fluid escaped and a solid pale-

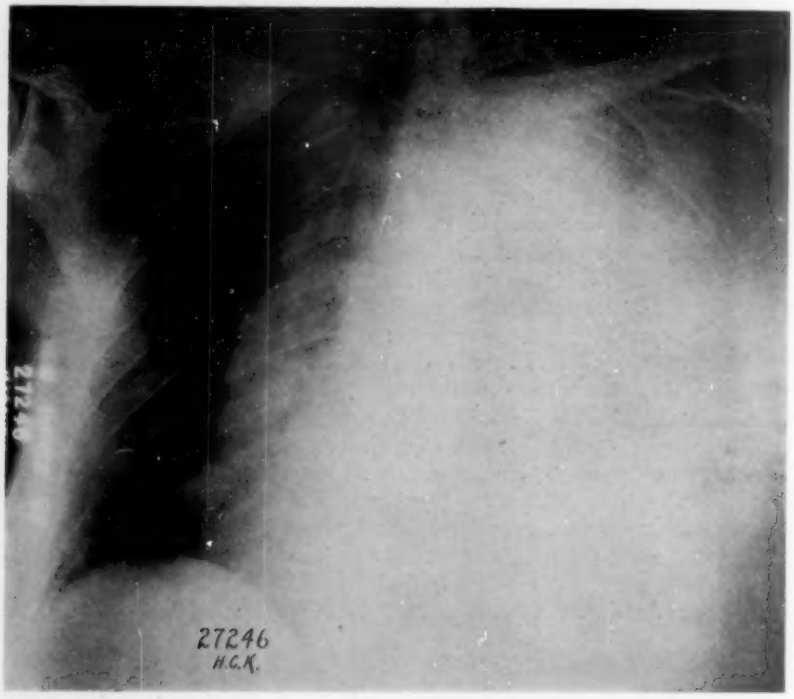

FIG. 1.—Chest before operation.

looking tumor, apparently filling the entire left thoracic cavity, became visible. It extended from the apex of the chest to the upper surface of the left diaphragm, pushing the latter downward and forward and forming a concavity instead of a convexity in the diaphragm.

The tumor was hard, not nodular, and adhered in many places to the parietal pleura. These adhesions were not firm and gave the impression that they were the result of repeated former punctures. The lung and heart could not be seen through the thoracic opening as the entire mediastinum and its contents were pushed over into the right pleural cavity. The adhesions were easily separated and the tumor became quite movable especially at its lower end. The upper end could not be reached through the opening. The movability of the mass made it appear probable that it could be removed. By this time the patient showed signs of weakness and having lost considerable blood it was thought best to interrupt the operation, especially as we had no knowledge of the extent to which the tumor might be attached medially; i.e., to the lung, heart, vessels and mediastinum, and, therefore, could not judge of the difficulties we might

encounter. The horseshoe flap was placed loosely over the tumor and the skin incision closed by interrupted sutures. At the close of the operation the patient's pulse was 120 and of good quality. The only time he had a weak and irregular pulse was when we explored toward the lung and mediastinum. The patient was not any the worse for the operation except that his hæmoglobin, which had been 80 per cent before, had dropped to 55 per cent.

November 11, four days after the operation, we transfused 350 cubic centimetres of blood and on the next day, November 12, followed it up with the final operation. The size of the tumor made it necessary to enlarge the incision and to remove more ribs in

FIG. 2.—Chest about three weeks after operation.

order to get it out of the thoracic cavity. Under para-vertebral anæsthesia the incision was extended upward to the top of the shoulder and three inches of the fifth, fourth and third ribs were removed and the remaining costal wall incised upward. Now almost the entire length of the tumor could be seen except the apex which, however, could be surrounded by the palpating fingers. Palpating the tumor it became evident that it could be lifted from the thoracic cavity. The lungs and heart were still not visible. Remembering our experience at the first operation when palpation in the region of the mediastinum had resulted in a small, irregular pulse and signs of collapse, I decided at this stage to give the patient gas anæsthesia to diminish and possibly avoid nerve reflexes and shock from handling the lungs and the heart.

Under gas anæsthesia, the tumor was gradually lifted from its bed and pulled outward. Now the pericardium with the slowly pulsating heart could be seen, the lung began to inflate slowly and move from the right pleural cavity across the spine to the left side. The middle lobe of the lung was densely adhering to the tumor to the extent of a fifty-cent piece. The rest of the lung was free. The arch of the aorta could easily be made out and a pedicle led from the upper and inner aspect of the tumor toward the mediastinum, but no attachment to any special organ could be made out. This

pedicle was surrounded by a ligature and then tied off. By this time and while attempting to separate the adhesions to the lower portion of the upper lobe of the lung respiration of the left lung became active and violent and the adhesion tore away, releasing the tumor and lung.

The tumor being out, the left lung now expanded with each inspiration and collapsed suddenly with the expiration, causing a violent flapping of the lung and mediastinum, and serious heart irregularity resulted. Separation of the pulmonary adhesion had resulted in a tear in the lung and a bloody foam exuded from it. I made an attempt to grasp this place with forceps and to sew the tear, but the breathing became so violent that further tears resulted in the attempt. It became evident that the patient's condition was critical and that the violent motion and flapping of the mediastinum must be stopped to avoid serious heart reflexes. Several large pieces of salt gauze packing were pushed against the lung and mediastinum and held there, steadying its action. The patient's condition now began to improve.

Fearing renewed cardiac disturbances the attempt to suture the lung was abandoned and the operation ended. The packing was left in place and the chest cavity closed,

FIG. 3.—Gross appearance of tumor. Long diameter—10¼ inches. Transverse diameter—6¼ inches. Largest circumference—25 inches. Short circumference—17 inches. Weight—4½ pounds.

permitting the ends of the gauze to protrude from the lower extremity of the incision. The pleura and intercostal muscles were reunited as far as possible and the skin closed by interrupted silkworm-gut sutures as far as the protruding drains. The entire length of the incision was eighteen inches.

Post-operative progress: There is not much to be said regarding the post-operative history. At no time did the patient seem to be in real danger. There was a moderate febrile reaction during the first week. December 1, i.e., nine days after the operation, it was deemed best to give the patient another blood transfusion from which he derived marked benefit. The gauze packs were gradually removed so that after two weeks a rubber drain could replace the gauze. Subsequent X-ray examination disclosed the fact that, while a pneumothorax was still present, the left lung was expanding gradually and the heart was approaching its normal position. The space in the right thorax was not encroached upon any longer and the lung was expanding normally. The mediastinum with the trachea had moved back to its position behind the sternum and the wound was heading satisfactorily. The patient gained in strength, had no dyspnœa, was rational and sat up in bed after eighteen days and left the hospital six weeks after the operation. The sinus in the left chest continued to discharge for several months. The

fistulous tract ultimately closed spontaneously. To all appearances the patient now is a well man, his strength has returned and he is back at his business.

Specimen (Fig. 3): An oval, solid tumor, having the shape and size of a football, pale in color, long diameter 10¼ inches, transverse diameter 6¼ inches, largest circumference 25 inches, short circumference 17 inches. Weight 4½ pounds.

Microscopic examination (Figs. 4 and 5): Slides show a highly cellular structure composed of atypical cells of the fibro-blastic series. The tumor cells are well differ-

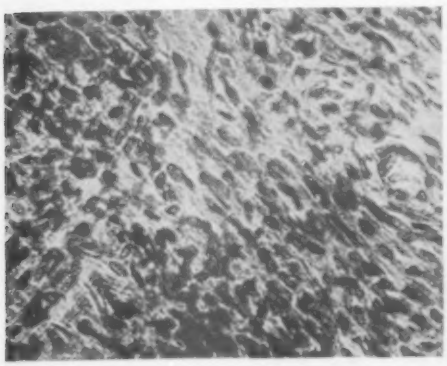

FIG. 4.—Slide—fibro-sarcoma—high power field.

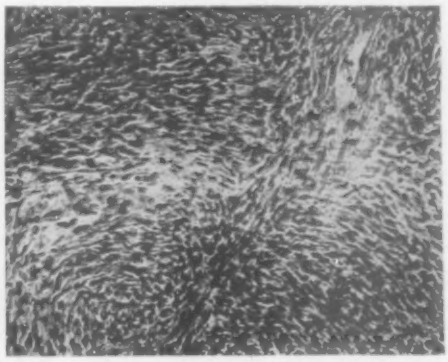

FIG. 5.—Slide—fibro-sarcoma—low power field.

entiated and mitotic figures are occasionally seen. Diagnosis: Fibro-sarcoma, low-grade malignancy.

Epicrisis: From the nature of the growth it is safe to assume that the tumor was of fairly slow development even though the subjective complaints were of but short duration. The rather acute development of symptoms can readily be explained on the assumption that it was the rapidly forming pleural exudate that finally brought on the severe cough and dyspnœa. But how explain the maniacal seizures during the last two weeks? In the absence of kidney complications, a toxæmia from that source can be excluded. It is more than likely that the extreme displacement of the heart with the resulting torsion and displacement of the large arteries and veins resulted in serious interference with the cerebral circulation. The veins being much more easily compressed through torsion and displacement of the heart than the arteries would cause venous cerebral congestion, insufficient oxygenation of the brain cells and consequent mental unbalance. Lack of nourishment to the brain and accumulation of toxæmia in the brain could induce mental disturbances in the case under consideration just as readily as these disturbances are frequently noticed in cases of prolonged cardiac failure. In the absence of fainting spells and facial pallor or signs of anæmia of the brain it could not have been the arterial blood supply that failed and it is most likely that the venous return was responsible for the occasional cerebral disorders, as the patient's face appeared rather flushed.

Inefficient respiratory exchange could, of course, also have resulted in toxicity of the blood and mental incoherence. However, such toxicity would most likely have led to coma rather than to violent maniacal seizures.

Hypoglycemia

To perform the operation in two stages was probably a wise thing to do under the circumstances as the loss of blood during the one stage had increased the anæmia decidedly. It appears to me now that with a little more forethought and better preparedness immediate suture of the lung might have been accomplished. A dull forceps, say a ring forceps, might have grabbed the lung with less danger of tearing. The lung could have been pulled away from the mediastinum and, by thus steadying it, we would have prevented the violent flapping of the mediastinum and avoided the serious pleural and mediastinal reflexes. Then suture of the torn lung tissue could have been done at leisure and more accurately. It also would have been possible to inflate the lung and to close the pleural cavity instead of draining it. More rapid and more complete expansion of the lung from the first would have been possible. As in the peritoneal cavity, closure of the pleura without drainage should be the aim. Even if a certain amount of infection of the pleural cavity can be anticipated and even if a serous or bloody exudate can be expected, I would still think it best to close the pleura without drainage. For if a pleural exudate should form and were large enough to need attention, aspiration can be done easily and repeatedly.

Finally, theoretically it must be considered an error not to have radiated the chest to prevent recurrence of the growth, but the patient refused. It is now three years since the operation and there is no evidence of recurrence.

CORRIGENDUM

On page 529, October ANNALS, 7th line from the top, instead of 1810 read 1910.

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